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CONTENTS

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Will the U.S. run out of oil in a few years?

Yes, said Navy Secretary Frank Knox last week before the House Naval Affairs Committee. He predicted a serious shortage of crude oil within a year. Within 14 years the U.S. will be a "have-not" nation in oil, he said, when the last drop of its oil fields is drained (if the present rate continues). Same day, Assistant Deputy Petroleum Administrator Robert E. Allen warned that the U.S. is threatened with a permanent oil shortage in two years unless "miraculously prompt" discovery of new fields offsets declining production. The U.S. must bring in 20,000 new wells a year, said he, to maintain present production.

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OCTOBER, 1943

BIG SNOWY GROUP: LITHOLOGY AND CORRELATION IN THE NORTHERN GREAT PLAINS[1]

EUGENE S. PERRY[2] AND LAURENCE L. SLOSS[2]
Butte, Montana

ABSTRACT

The Big Snowy group consists of a middle and upper Mississippian series of shales, sandstones, limestones, and evaporites. Recently drilled deep wells and new interpretations of older wells in Montana and the Dakotas yield information which makes possible further considerations on the subsurface extensions, correlations, and lithology of the Big Snowy sediments in the Williston basin. A lateral tracing of persistent lithologic units, the recognition of the removal of certain units by Mississippian erosion, and the addition of a basal unit not present in outcrop areas make possible satisfactory correlation of the subsurface Big Snowy in the Williston basin.

Paleogeographic studies reveal the influence of the ancestral Sweetgrass arch on the character of clastic sediments, in the Big Snowy group, and indicate the possibility of favorable reservoir conditions in untested areas adjacent to that positive element.

INTRODUCTION

Sediments of late Mississippian age have been a source of difficulty in the correlation of well data in widely separated deep test wells in the Northern Great Plains, resulting in a lack of agreement among geologists working this area. The writers have attempted in this paper to clarify some of the controversial problems by means of re-examination of old data, and addition of new data made available by the recent drilling of several deep tests. Furthermore, these strata are important in the current search for oil in the Northern Great Plains in view of the facts that they have yielded some oil, and that their geologic age and depositional environment is similar to the highly productive strata of the Illinois basin.

The following wells upon which sample data were available are the basis for the subsurface information in this paper.

Arro Oil and Refining Co.–California Co's. Charles No. 4, Sec. 21, T. 15 N., R. 30 W., Mosby dome, Petroleum County, Montana

[1] Published with the permission of the director of Montana Bureau of Mines and Geology.

[2] Department of geology, Montana School of Mines.

Carter Oil Co's. Northern Pacific No. 1, Sec. 19, T. 4 N., R. 62 E., Baker-Glendive anticline, Fallon County, Montana

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Carter Oil Co's. Semling No. 1, Sec. 18, T. 141 N., R. 81 W., Oliver County, North Dakota

Carter Oil Co's. South Dakota Stratigraphic Test No. 1, Sec. 34, T. 118 N., R. 78 W., Potter County, South Dakota

Carter Oil Co's. S. Dakota Stratigraphic Test No. 2, Sec. 12, T. 9 N., R. 27 E., Stanley County, South Dakota

State Royalty Petroleum Co's. State No. 1, Sec. 35, T. 4 N., R. 1 E. Camp Crook anticline, Harding County, South Dakota

The writers wish to acknowledge assistance rendered by various individuals and companies active in the Northern Great Plains. In particular, appreciation is expressed for help given by O. A. Seager of The Carter Oil Company and Karl A. E. Berg of the Northern Pacific Railway Company. The research involved in this paper has been made possible by the support of the Montana Bureau of Mines and Geology.

DEFINITION

The Big Snowy group was named by Scott[3] to supplant the name Quadrant as applied to middle and late Mississippian sediments in central Montana. According to Scott,[4]

> The group of strata that occurs between the Madison limestone and the Amsden formation of central Montana has been designated the Big Snowy group, because of its extensive distribution and excellent exposures in the Big Snowy Mountains.

Scott divided the group into three formations which, in descending order, are: Heath, Otter, and Kibbey. The names, Kibbey and Otter, had previously been given by Weed[5] to strata which he included in the "Quadrant" formation of the Little Belt Mountains. Scott restricted the usage of the term Otter and applied the name Heath to the upper formation of the group.

The term Charles has been introduced by Seager[6] "to describe that series of beds lying between the basal member of Scott's Big Snowy group and the Madison," and Seager amended the Big Snowy group to include the Charles formation.

DISTRIBUTION

The sediments included in the Big Snowy group are present in the Williston basin underlying central and eastern Montana, northwestern South Dakota,

[3] H. W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour Geology*, Vol. 43 (1935), pp. 1011–32.

[4] *Ibid.*, p. 1023.

[5] W. H. Weed, "Geology of the Little Belt Mountains, Montana," *U. S. Geol. Survey 20th Ann. Rept.* (1899), pp. 22–23.

[6] O. A. Seager, "Test on Cedar Creek Anticline, Southeastern Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), p. 864.

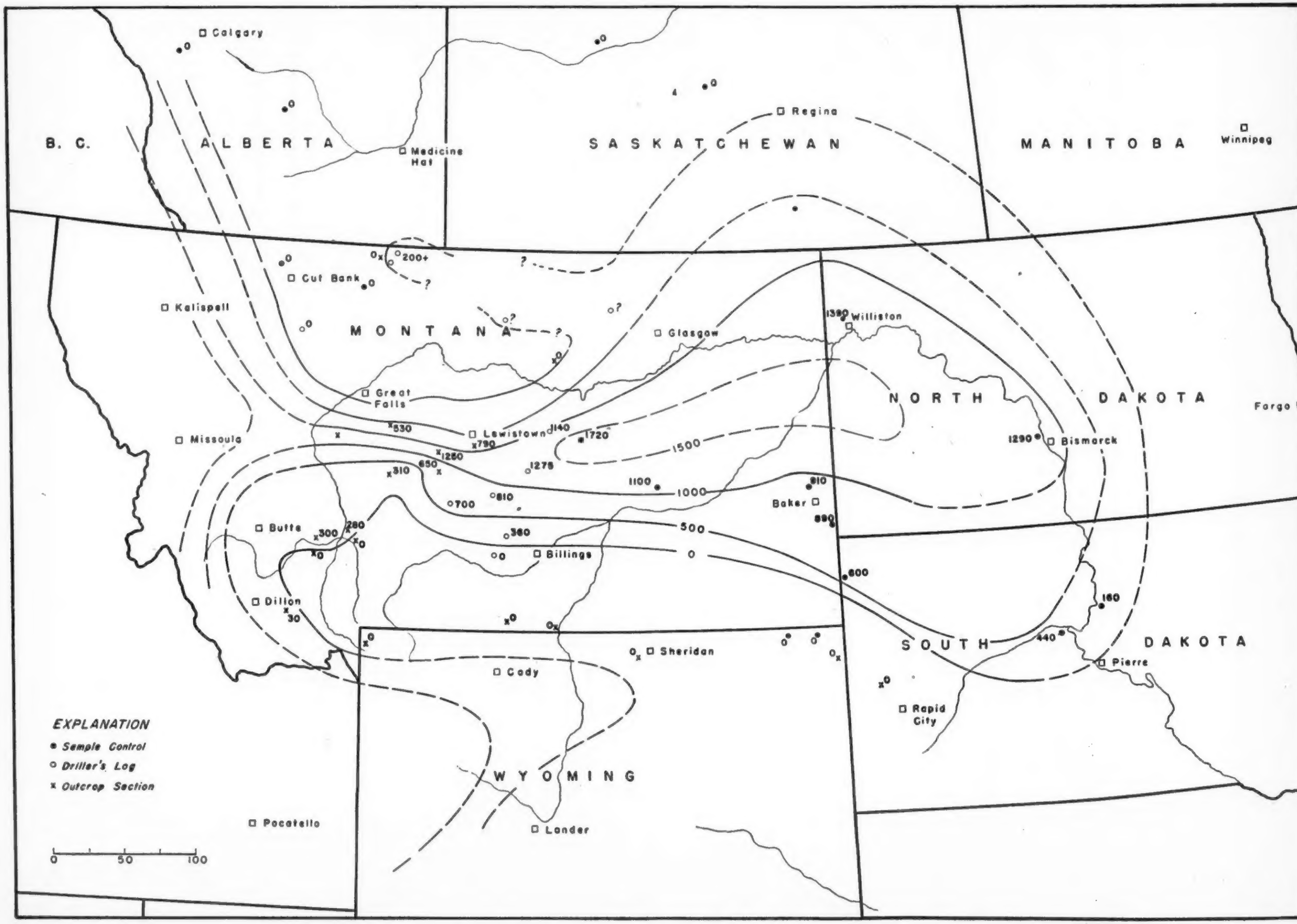


FIG. 1.—Isopach map of Big Snowy group showing distribution and thickness subsequent to late Paleozoic and early Mesozoic erosion.

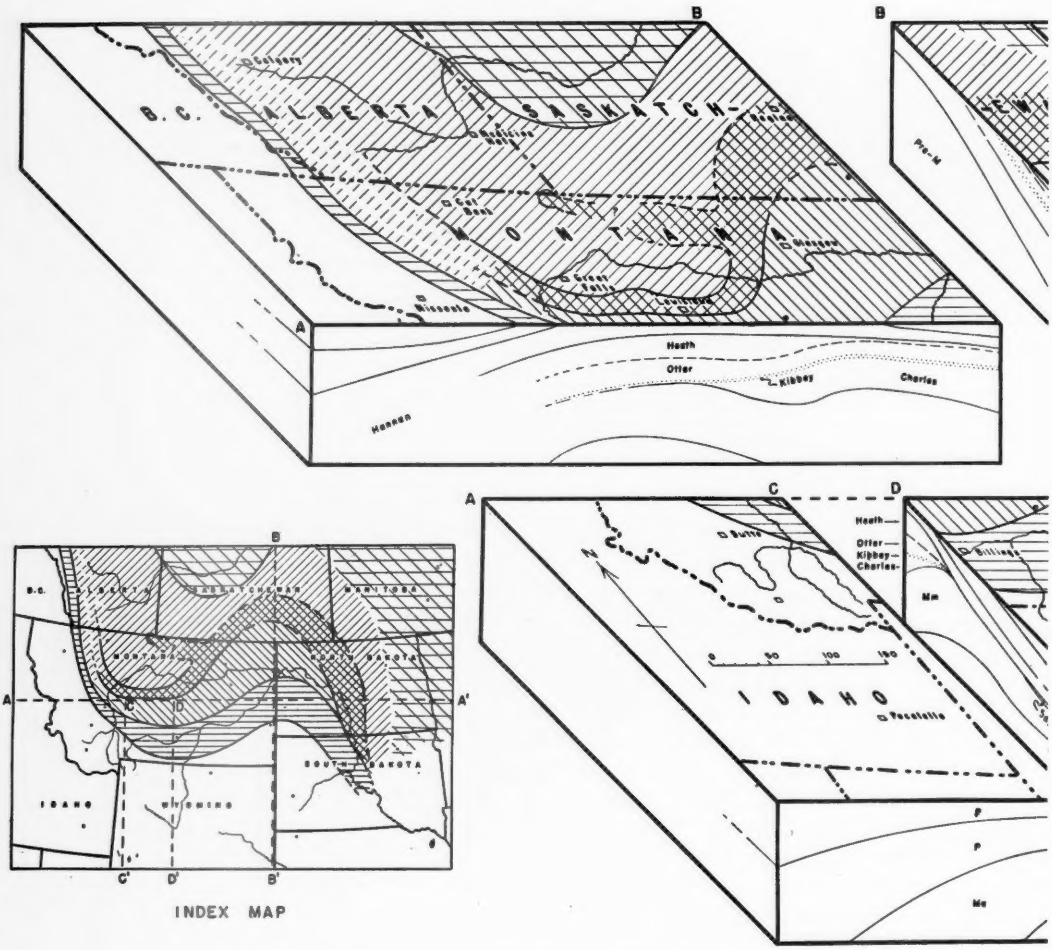
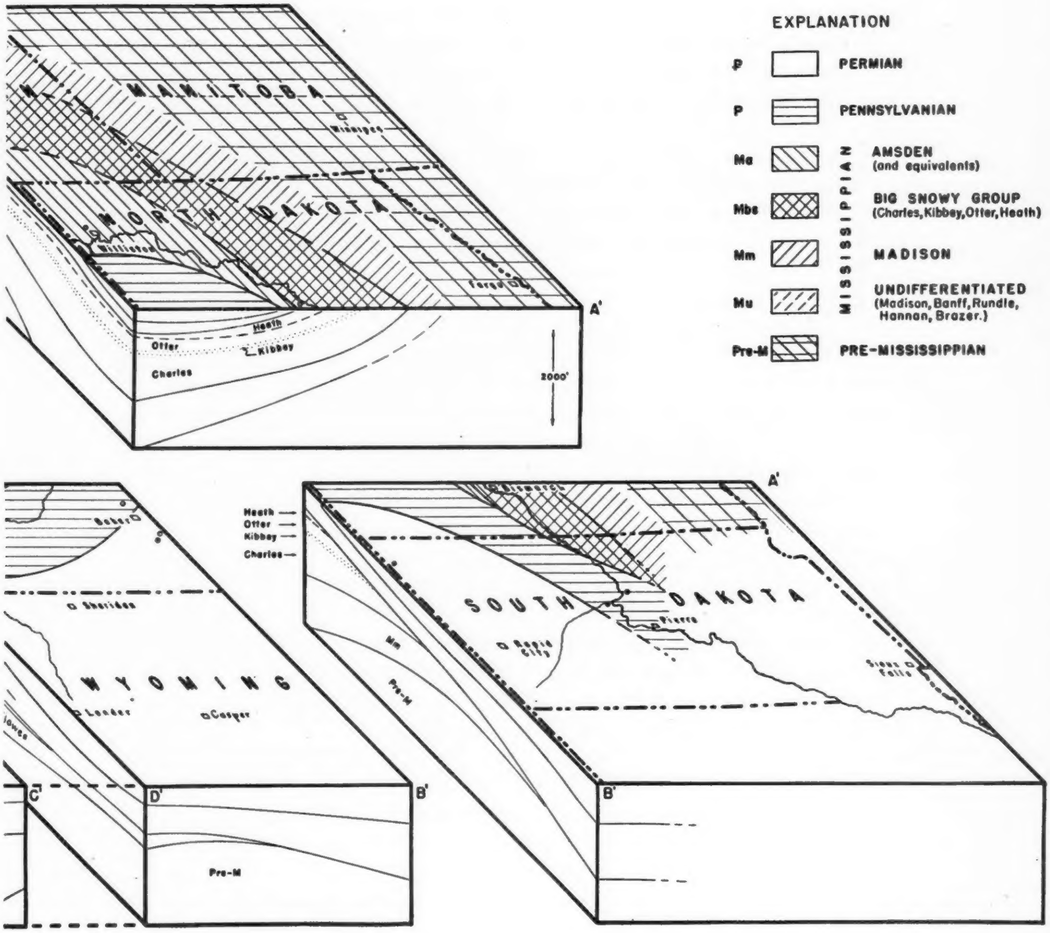


FIG. 2.—Block diagrams illustrating post-Paleozoic–pre-Mesozoic paleogeology



and relationships of late Paleozoic formations in Northern Great Plains.

western North Dakota, and southern Saskatchewan. Westward these sediments merge into the Mississippian limestones of the Cordilleran trough, where the names Brazer (Idaho), Hannan (northwestern Montana), and Rundle (British Columbia and Alberta) have been applied. A thin series of equivalent sediments, the Sacajawea formation, was deposited in north-central Wyoming. The Big Snowy and Sacajawea areas of deposition were separated by an area of erosion or non-deposition which extended westward from the Black Hills to the locality of Three Forks, Montana.

On the north the present extent of Big Snowy sediments is limited by erosion which took place on the ancestral Sweetgrass arch prior to mid-Jurassic time. It is not now possible to determine how far north the original basin extended, although it may have spread into southeastern Alberta and southwestern Saskatchewan.

The present configuration of the bounding line on the eastern side of the Sweetgrass arch, now buried beneath Jurassic sediments, may be shown by current and future drilling to have numerous bulges and recessions; and scattered wells indicate erosional remnants beyond the bounding line. In particular, The California Company's Johnson-Hobson test No. 1 in the Bowes gas field (Sec. 9, T. 31 N., R. 19 E.), the Smith-Gulick-Sorenson-Smith well No. 1 just east of the Sweetgrass Hills (Sec. 23, T. 37 N., R. 7 E.), and the Bowdoin Oil and Gas Company's well No. 2 in the Bowdoin-Saco gas field (Sec. 35, T. 32 N., R. 32 E.) show sediments characteristic of the upper part of the Big Snowy group immediately beneath the Jurassic. Other wells in this general region, and outcrop areas in the Little Rocky Mountains and the Sweetgrass Hills, show Madison strata beneath the Jurassic.

The northeastern, eastern, and southeastern margins are indeterminate at present due to lack of data; but eastward the margin is known to lie between central North Dakota and the belt of early Paleozoic outcrops adjacent to the Canadian shield in Manitoba and western Minnesota.

STRATIGRAPHIC RELATIONS

The Big Snowy group, wherever encountered, lies on the Mission Canyon limestone of the Madison group (Pahasapa of South Dakota).[7] Where the Charles formation is present, the division between the Big Snowy group and the Madison group is difficult to determine, because of the gradational transition from normal marine limestone of the Madison to the anhydrite-bearing limestones of the Charles. Where the Charles is missing, as in the Big Snowy and Belt mountains of central Montana, the red sands of the Kibbey rest disconformably on the channeled surface of the Madison.

The Big Snowy group is overlain by what the writers term Amsden throughout its extent, except for a narrow zone on the flanks of the ancestral Sweetgrass

[7] L. L. Sloss and R. H. Hamblin, "Stratigraphy and Insoluble Residues of the Madison Group (Mississippian) of Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), p. 309.

arch in central Montana, where pre-Jurassic erosion removed the Amsden, but not all of the Big Snowy, prior to Jurassic deposition. Furthermore, the writers are in doubt about the age of the strata overlying the Big Snowy in central North Dakota and South Dakota where the overlying strata are not readily correlated with areas on the west. It is probable that the red beds overlying the Big Snowy in The Carter Oil Company's Semling No. 1 in North Dakota are Triassic in age, and that the pink and white, sandy, calcareous beds overlying the Big Snowy in The Carter Oil Company's stratigraphic tests near Pierre, South Dakota, are Pennsylvanian in age.

The term Amsden has been nearly obliterated from geologic literature by the work of C. C. Branson,[8,9] and Thompson and Scott.[10] These writers, recognizing that the Amsden, as defined by Darton,[11] included strata of both Pennsylvanian and Mississippian age, have now placed all Pennsylvanian strata in the Tensleep (Quadrant), and the Sacajawea formation was established to include the lower beds bearing a Ste. Genevieve fauna. Between the redefined Tensleep and the Sacajawea are left orphaned strata bearing a Chester fauna. These latter beds may be traced throughout central Montana and much of the Williston basin, overlapping the truncated edges of Big Snowy strata, and transgressing the peninsula area devoid of both Big Snowy and Sacajawea sediments along the Montana-Wyoming border. It is the writers' contention that the name Amsden should be retained for these strata in Montana and the Williston basin for the following reasons.

1. These strata form a cartographic unit which can be mapped in the field.
2. They form a lithologic unit which can be recognized in well cuttings.
3. They rest with overlap and angular unconformity on the Big Snowy group, and thus can not be placed in that group as suggested by Scott.[12]
4. They bear a fauna that is younger than Sacajawea and Big Snowy, and preponderantly older than Pennsylvanian.

The appearance of Pennsylvanian elements in the fauna of the upper beds of the Amsden, without a discernible lithologic break, is not sufficient reason for splitting this formation into units that can not be mapped in the field, particularly at a time when the existence of Mississippian and Pennsylvanian as separate systems is open to controversy. "A formation is a lithogenetic unit; it is a se-

[8] C. C. Branson, "Stratigraphy and Fauna of the Sacajawea Formation, Mississippian of Wyoming," *Jour. Paleontology*, Vol. 11 (1937), pp. 650–60.

[9] C. C. Branson, "Pennsylvanian Formations of Central Wyoming," *Bull. Geol. Soc. America*, Vol. 50 (1939), pp. 1199–1226.

[10] M. L. Thompson and H. W. Scott, "Fusulinids from the Type Section of the Lower Pennsylvanian Quadrant Formation," *Jour. Paleontology*, Vol. 15 (1941), pp. 349–53.

[11] N. H. Darton, "Geology of the Bighorn Mountains," *U. S. Geol. Survey Prof. Paper 51* (1906), pp. 31–34.

[12] H. W. Scott, "Ostracodes from the Upper Mississippian of Montana," *Jour. Paleontology*, Vol. 16 (1942), p. 152.

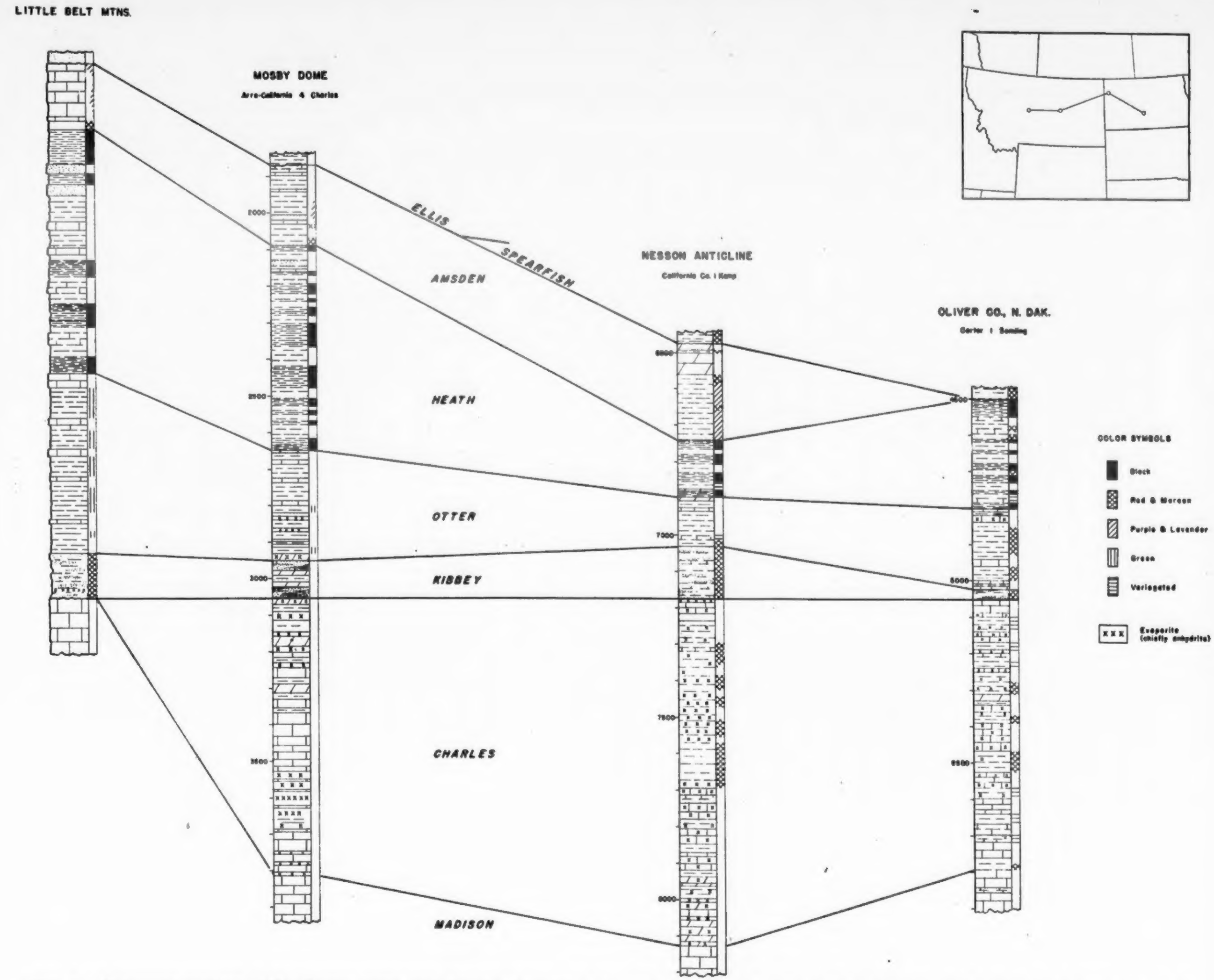


FIG. 3.—Columnar sections of Big Snowy group and Amsden formation arranged as west-east cross section along approximate axis of Williston basin.

quence of strata which the geologist can map."[13] In practical field and subsurface geology a formation can not be closely delimited by paleontologic time boundaries. If the name, Amsden, is not retained a new term must be coined for the strata

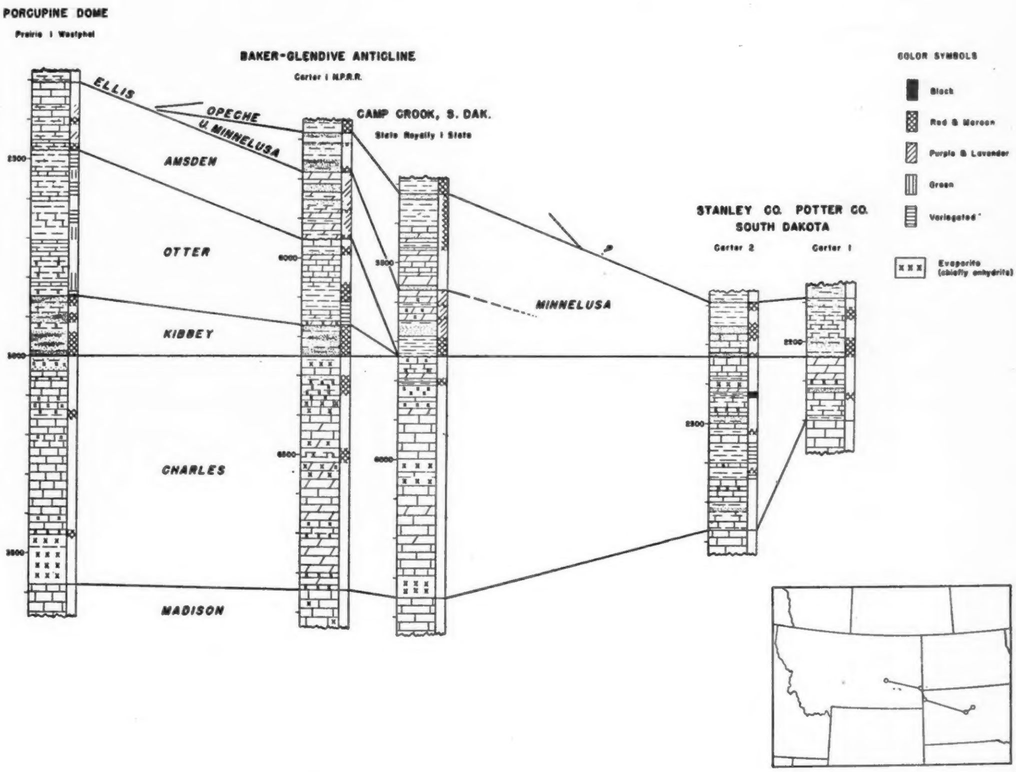


FIG. 4.—Columnar sections of Big Snowy group and Amsden formation arranged as west-east cross section of southern part of Williston basin.

which are readily divisible from the Tensleep or Quadrant above, and the Big Snowy group below. The writers see no necessity for such a step at present.

GEOLOGIC AGE

The precise time limits of the Big Snowy group in terms of the standard scale have not been definitely established, nor are they likely to be until the prolific brachiopod fauna of the group has been studied and interpreted in detail. On the

[13] H. G. Schenck *et al.*, "Stratigraphic Nomenclature," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), p. 2201.

basis of preliminary investigation of the megafauna of the Otter and Heath formations Scott states:

It is probable that this group will be found to range from Middle Valmeyer to Middle

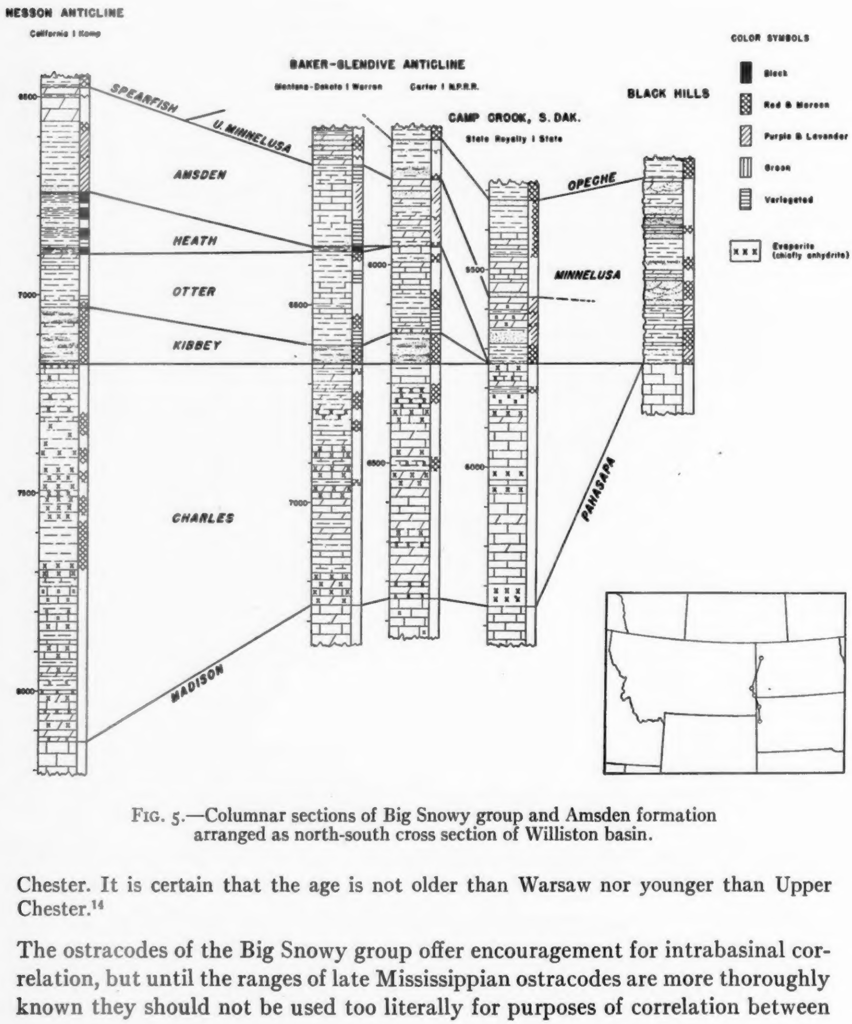


FIG. 5.—Columnar sections of Big Snowy group and Amsden formation arranged as north-south cross section of Williston basin.

Chester. It is certain that the age is not older than Warsaw nor younger than Upper Chester.[14]

The ostracodes of the Big Snowy group offer encouragement for intrabasinal correlation, but until the ranges of late Mississippian ostracodes are more thoroughly known they should not be used too literally for purposes of correlation between

[14] H. W. Scott, "Some Carboniferous Stratigraphy in Montana and Northwestern Wyoming," *Jour. Geology*, Vol. 43 (1935), p. 1031.

the Illinois and Williston basins. According to Scott the ostracodes of the post-Charles Big Snowy group, particularly those of the Otter formation, "are closely related to those described from the Chester of Illinois, especially from the Golconda, Menard, and Clore formations."[15]

For the present it is sufficient to state that the Big Snowy is younger than Osage (Mission Canyon) and older than late Chester (Amsden). It seems probable that the disconformity between the Madison and Kibbey represents the widespread break between Osage and Meramec; but neither the time involved in the hiatus, nor that part of it represented in the center of the basin by Charles sediments, can be measured at present.

LITHOLOGY AND CORRELATION

The division and correlation of the Big Snowy group, from well to well, and from subsurface to outcrop, has been one of the most difficult problems in the subsurface geology of the Northern Great Plains. This problem has been attacked in two different manners: (1) an explanation of the apparent difference in lithologic character from place to place through changes in facies (Jones);[16] (2) a lateral tracing of persistent lithologic units, the recognition of removal of certain units by pre-Amsden erosion, and the addition of a basal unit not present in the outcrop area (Carmody,[17] Seager, *et al.*[18]).

The writers of this paper favor the latter method and have been able to trace the sandy zone of the Kibbey immediately overlying the limestones and anhydrites of the Charles eastward into the wells of the Williston basin. This zone has been taken as a datum; and in Figures 3, 4, and 5, the base of the Kibbey has been plotted as a horizontal line with the Charles below and Kibbey, Otter, and Heath above. In this manner a clearer picture of the relationship of units from well to well is made apparent. Until the microfauna of the Mississippian of the Williston basin is known in more detail, the most satisfactory correlations are those based on lithology, as have been attempted by the writers of this paper.

Heath.—In outcrop the Heath is characterized by an abundance of black, fissile, conodont-bearing shales, intercalated with gray shales, massive brownish sandstones containing plant fragments and commonly cross-bedded, and minor gray limestones.

The black shales yield no petroleum with carbon tetrachloride; however, destructive distillation yields petroleum compounds in excess of 15 gallons to the ton from some of the shales, and some material will hold a flame upon heating

[15] H. W. Scott, "Ostracodes from the Upper Mississippian of Montana," *Jour. Paleontology*, Vol. 16 (1942), p. 152.

[16] C. T. Jones, "Contribution to Stratigraphy of Northern Great Plains," *Guide Book Kansas Geol. Soc. 14th Annual Field Conference* (1940), p. 132.

[17] R. A. Carmody, *Guide Book Kansas Geol. Soc. 14th Ann. Field Conference* (1940), p. 137.

[18] O. A. Seager *et al.*, "Stratigraphy of North Dakota," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26 (1942), p. 1420.

with a match. The sandstones, ranging up to 20 feet in thickness, are composed of well sorted clear quartz grains of low roundness and sphericity and commonly displaying secondary enlargement.

The Heath retains remarkably uniform lithologic characteristics eastward in wells into central North Dakota, the black shale persisting from top to bottom. A change noted is a progressive diminution in thickness and grain-size of the sandstones with increasing distance from the ancestral Sweetgrass arch. Thus the sandstones in the Big Snowy Mountains total 62 feet and are composed of grains ranging from 0.35 millimeter to fine conglomerate, while in the California's Kamp No. 1 and in the Carter's Semling No. 1 only a few thin sands occur, with particle diameters less than 0.15 millimeter. South of the Little Belt and Big Snowy mountains sandstones are trivial or missing in the Heath section.

The thickness of the Heath appears to be greatest along the axis of the basin (625 feet, Little Belt Mountains; 560 feet, Arro Oil and Refining Company and The California Company's Charles No. 4). As shown on Figure 2, Section *BB′*, and Figure 5, the Heath may be traced southward from The California Company's Kamp No. 1 to a thin remnant in the Montana-Dakota Utilities' Warren No. 1, but is missing in wells on the south end of the Baker-Glendive anticline. This southward wedging-out of the Heath is due to pre-Amsden erosion affecting the southern margin of the Williston basin eastward from the Porcupine dome.

Otter.—In outcrop the Otter formation is characterized by vivid green shales, intercalated with gray shales and fossiliferous oölitic limestones. In the subsurface the green shales can not be traced far east of the Big Snowy Mountains, being replaced by variegated and red shales, apparently as a result of more complete oxidation of iron compounds. Moreover, the eastward extensions of the Otter exhibit a higher percentage of limestone, usually light in color, oölitic, and highly ostracodal. A few thin anhydrite beds and anhydritic limestones were noted in most cuttings from the Otter.

The Otter attains its greatest thickness (500 feet) in the Little Belt Mountains. Major variations in the subsurface thickness of the formation depend on the depth of pre-Amsden erosion which completely removed the Otter south and southeast of The Carter Oil Company's N. P. No. 1 (southeastern Montana). It appears that the Otter shale facies of sedimentation replaced Kibbey deposition earlier in some areas than in others, leading to a thickening of the Otter where the Kibbey is thin, and *vice versa.*

Kibbey.—In outcrop the Kibbey formation is dull, brick-red, dolomitic, shaly sandstone, devoid of fossils, and locally containing beds of gypsum. The material is poorly sorted, the particles ranging from silts to 0.5 millimeter. The grains have a moderately high roundness and sphericity, and most of them are frosted and pitted. The grains are mainly quartz of several varieties, some containing black, needle-like inclusions. Grains of chert up to 10 per cent of the total and numerous accessory minerals are present. The chert may well have come from the weathering of Madison limestone, which contains much chert, but the

Madison limestones do not contain sufficient quartz grains in proportion to chert to account for the concentration of quartz in the Kibbey sand. Furthermore, the bulk of Madison quartz grains are angular, euhedral, and small in diameter.[19] Toward the southern margin of the outcrop area, the Kibbey becomes increasingly dolomitic with a decrease in grain-size, until the formation is not recognizable as a sandstone; however, the red color persists in the outcrop areas (central Montana). The Kibbey rests disconformably on the Mission Canyon limestone (Madison), filling channels and solution cavities, some of which may be 300 feet beneath the top of the limestone.

Eastward from the Big Snowy Mountains the Kibbey may be traced in well records, through much of the Williston basin into central North Dakota, maintaining the red color and most of the lithologic characteristics of the outcrop areas. In well cuttings the Kibbey sand may be differentiated from those of the Heath by the characteristic poor sorting, high roundness, frosted surfaces of the grains, and the variety of mineral constituents and types of quartz. In the deep tests of North Dakota the Kibbey sand is noticeably finer than elsewhere, being little more than calcareous silt with a few scattered grains up to 0.25 millimeter in The Carter Oil Company's Semling No. 1.

Where the Charles formation is present the base of the Kibbey is not easily defined, because a gradational transition is present from the anhydritic limestone of the Charles into the sandy beds of the Kibbey. The writers have placed the contact at the top of the dominantly limestone and anhydrite series, as this seems to make the most easily recognized break, even though a few thin sandy zones may thus be included in the upper Charles.

South of the wells on the Little Beaver dome (southeastern Montana), pre-Amsden erosion has removed the Kibbey so that it is absent in the State Royalty Petroleum Company's State No. 1, and in The Carter Oil Company's stratigraphic tests in central South Dakota (Fig. 2, sec. *BB'*).

Charles.—The Charles formation has not been recognized in outcrop, but has the widest subsurface distribution of any unit of the Big Snowy group. The formation is characterized by light-colored earthy limestones and dolomites (in places oölitic, commonly anhydritic), interbedded with evaporities (chiefly anhydrite) in beds approaching 100 feet in thickness. Minor amounts of red shale are present in most sections penetrated, but in The California Company's Kamp No. 1 approximately half of the Charles is composed of anhydritic and salty red and variegated shales. The presence of sandy zones near the top of the unit has already been noted. Sand is also prominent in the two stratigraphic tests in central South Dakota, presumably as a result of proximity to the southeastern margin of the basin.

That the contact between the Charles and the Madison is difficult to determine to the satisfaction of all is evidenced by the variety of opinions ex-

[19] L. L. Sloss and R. H. Hamblin, *op. cit.*, p. 329.

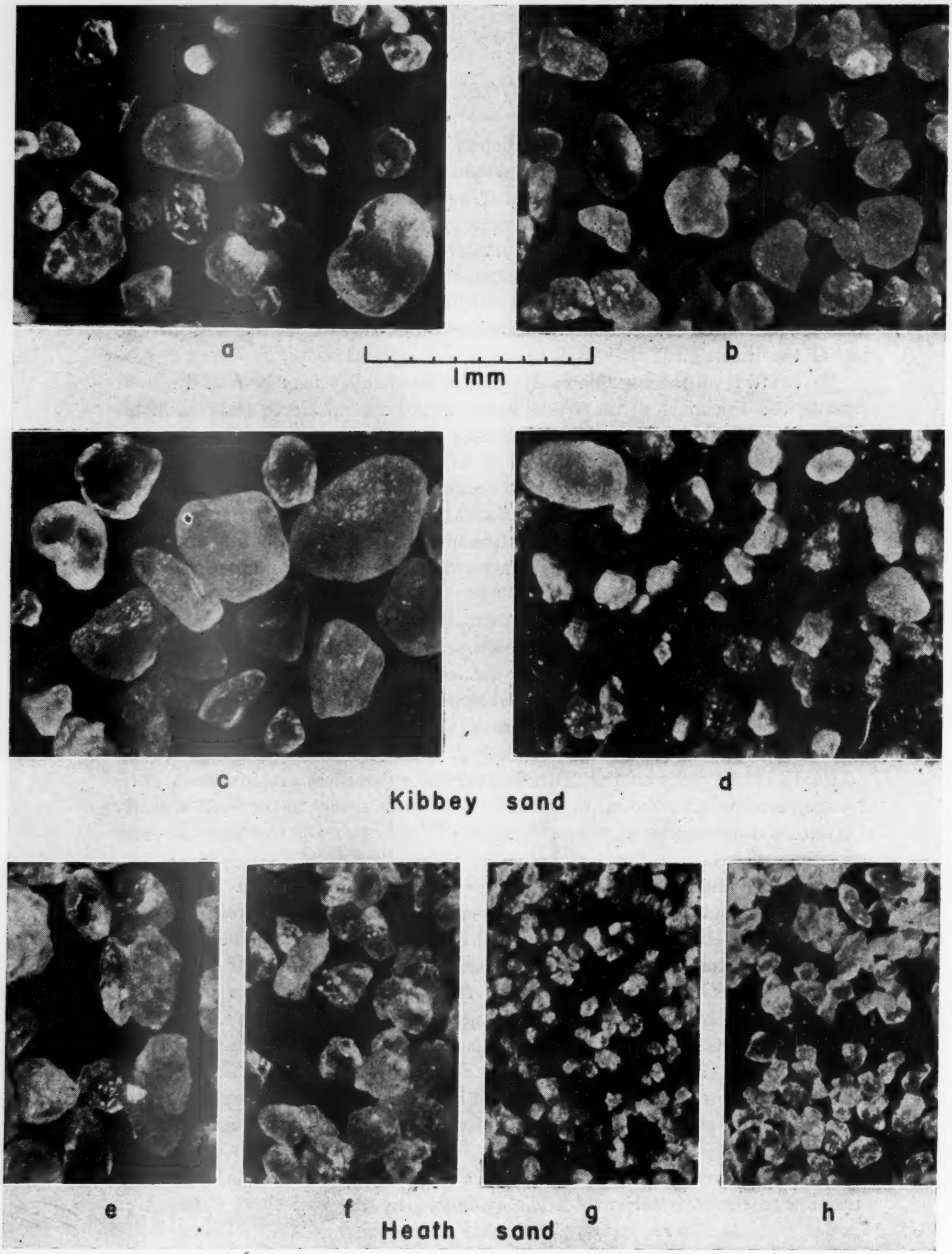


FIG. 6.—Photomicrographs of typical Kibbey and Heath sand grains. *a*. Kibbey, surface exposure, Big Snowy Mountains. *b*. Kibbey, Arro Oil and Refining Company–California Company's Charles No. 4, Sec. 21, T. 15 N., R. 30 W., Petroleum County, Mont., 2,950–3,000 feet. *c*. Kibbey, Carter Oil Company's N. P. No. 1, Sec. 19, T. 4 N., R. 62 E., Fallon County, Mont., 6,230–6,240 feet. *d*. Kibbey, Carter Oil Company's Semling No. 1, Sec. 18, T. 141 N., R. 81 W., Oliver County, N. Dak., 4,600–4,610 feet. *e, f*. Heath, surface exposure, Big Snowy Mountains. *g*. Heath, Arro Oil and Refining Company–California Company's Charles No. 4, 2,440–2,450 feet. *h*. Heath, Carter Oil Company's Semling No. 1, 4,600–4,610 feet. Same enlargement in all photographs.

pressed.[20,21,22,23,24] The writers are in agreement with Seager *et al.* and Carmody that the most logical and easily defined contact lies below the lowest major massive anhydrite and just above a zone of porosity which is a recognizable zone throughout the Williston basin. Anhydrite occurs below this level, but as secondary fillings of cracks and vugs in the limestone, rather than as the definite beds typical of the Charles. Moreover, the cuttings indicate a change from earthy limestone in the Charles to dense or crystalline limestone in the Madison at the contact chosen by the writers.

The greatest thickness of Charles penetrated is 950 feet in The California Company's Kamp No. 1, although an average in seven wells is about 600 feet. West of Devil's Basin and Kootenai dome the Charles thins within a short distance, and it is absent in the Big Snowy Mountains 30 miles away (Fig. 2, *AA'*). Similarly, the Charles is 600 feet thick in the State Royalty Petroleum Company's State No. 1 and is absent in the Black Hills 50 miles south.

PALEOGEOGRAPHY

At the end of Osage time the Madison sea reached its greatest extent, spreading eastward from the Cordilleran trough over the Northern Great Plains. Early in Meramec time, this sea contracted, receding into the Cordilleran trough, leaving a more or less isolated remnant occupying the center of the Williston basin, and laying bare the adjacent areas to action of erosion and solution (Fig. 7, B). This accounts for the disconformable relationship between the Kibbey and Madison in areas where the Charles is lacking. In the central part of the Williston basin conditions of sedimentation gradually changed from normal marine (Madison) limestone deposition to one of mixed evaporites and limestone (Charles) as the concentration of salts increased with the contraction and isolation of the sea. It is probable that contributions of marine water were added intermittently from the geosyncline to the west, thus resulting in an alternation of anhydrite and limestone of the Charles formation.

At the beginning of Kibbey time a slight submergence resulted in the transgression of marine waters from the Cordilleran trough over the barrier which had isolated the Williston basin (Fig. 7, C). Kibbey sediments, as well as Otter and Heath sediments, are not believed to have been deposited on the minor positive area along the Montana-Wyoming state line. In west-central Montana where no deposition took place in Charles time the calcareous sands of the Kibbey were laid down on the eroded surface of the Madison. In the central part of the Willis-

[20] F. W. De Wolf and W. W. West, "Stratigraphic Studies of Baker-Glendive Anticline, Eastern Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 461–75.

[21] D. M. Allen, "Stratigraphic Studies of Baker-Glendive Anticline, Eastern Montana," *ibid.*, pp. 1246–50.

[22] O. A. Seager *et al.*, *op. cit.*, p. 1420.

[23] C. L. Jones, *op. cit.*, p. 133.

[24] R. A. Carmody, *op. cit.*, p. 137.

ton basin the non-clastic deposition of the Charles merged gradually into the sandy Kibbey. The character of the sand grains and the proportion of quartz to chert indicates that the sands of the Kibbey did not come from the weathering of the Madison, but had a more distant source. A relatively larger particle size of the sand grains in the northwestern and southeastern portions of the Williston basin suggests relationship to erosion in the ancestral Sweetgrass arch and the

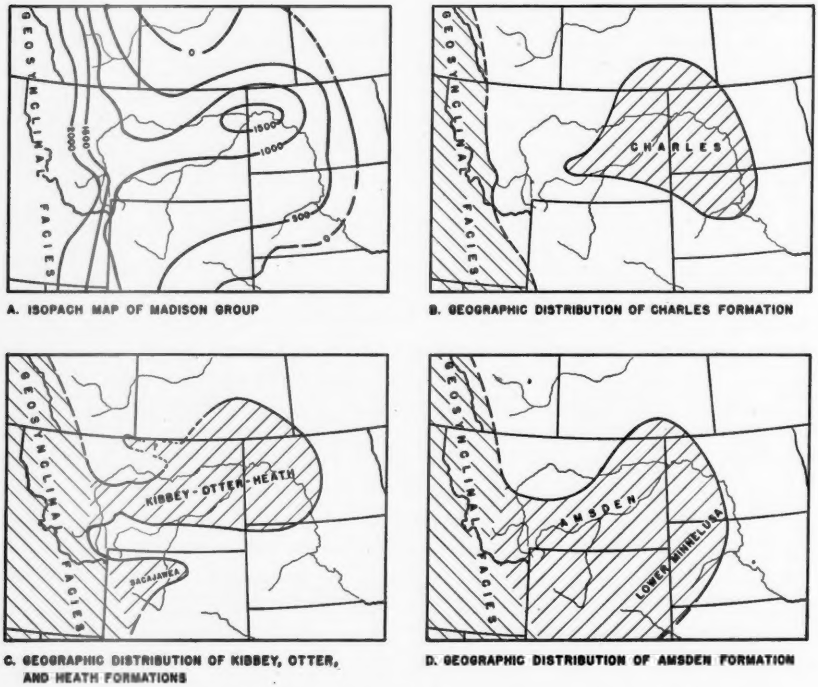


FIG. 7.—Geographic distribution of Mississippian formations in northern Rocky Mountains and Northern Great Plains.

Sioux uplift. Deposition of limestone in the trough area of western Montana in Kibbey time indicates that the source of sands was not in Cascadia.

Otter time was characterized by more or less normal marine deposition of alternating limestone and shale. The predominance of shale in the western portion of the area of Otter deposition again suggests influence of erosion on the ancestral Sweetgrass arch, while the oölitic and highly fossiliferous limestones are indicative of shallow warm seas.

Although the precise time equivalency of the Sacajawea of Wyoming to the Big Snowy group as a whole is not definitely known, it seems probable that the

sea in which the Sacajawea was deposited developed mainly in Otter time, although it was physically separate except for connections through the Cordilleran trough in which were deposited Brazer and equivalent limestones.

The normal marine conditions of Otter time gave way abruptly to an alternating continental and marine environment of Heath time. The abundant black shales of the Heath indicate a confined body of water of the lagoonal or estuarine type, such as promoted the accumulation of organic débris, and which was inimical to all but a few specialized forms of life. From time to time normal marine sedimentation prevailed, and fossiliferous shales and limestones were deposited. The presence in sandstone of plant fragments of the *Lepidodendron* type, the existence of coal (Montana-Dakota Utilities' Warren No. 1, The California Company's Kamp No. 1), and the cross-bedding of some sandstone members indicate periodic continental conditions.

The progressive diminution in thickness and grain-size of the Heath sandstones away from the ancestral Sweetgrass arch indicates that erosion related to that positive area was responsible for their distribution.

After the deposition of the Heath, in the latter part of Chester time, erosion prevailed along the southeastern margin of the Williston basin, as a result of which south of the north end of the Baker-Glendive anticline successively older units of the Big Snowy group lie with slight angular unconformity beneath the Amsden. Further evidence of this erosional unconformity is a limestone conglomerate in the State Royalty Petroleum Company's State No. 1 where the Amsden rests on the Charles formation. In the Three Forks area the Heath, Otter, and Kibbey show no truncation, each thins individually toward the south, and all are absent through non-deposition south of the Three Forks area. In the central part of the basin there is no evidence of erosion between the Heath and Amsden.

Perhaps the greater thickness of the Mississippian portion of the Amsden of central Montana, as compared with that of Wyoming, may be explained by the initiation of Amsden sedimentation in the Williston basin, while areas at the south were undergoing erosion or non-deposition. In any case, Amsden and equivalent sediments blanketed the Williston basin, the Wyoming-Montana peninsular area of Big Snowy time, and much of Wyoming. The sandy facies of these sediments (lower Minnelusa) reflects the influence of the Cambridge arch on the southeast.

Sedimentation in Amsden time appears to have been influenced by the areal distribution of Big Snowy sediments, as indicated by the presence of red shaly basal sands closely resembling the Kibbey where Big Snowy sediments are absent and a thinning or lack of this type of material at the base of the Amsden where Big Snowy sediments underlie it.

Widespread early Mesozoic erosion prior to deposition of the Jurassic Ellis formation caused removal of Big Snowy and later Paleozoic sediments from a large area on the ancestral Sweetgrass arch. Within a very short distance north

of the Belt and the Big Snowy mountains the Ellis formation rests successively on Amsden, Big Snowy, and finally Madison sediments. This belt of termination of Big Snowy sediments by pre-Ellis erosion probably continues northeastward along the eastern flank of the ancestral Sweetgrass arch forming an irregular pattern with numerous bulges and outlying erosion remnants.

PETROLEUM POSSIBILITIES

Oil has been produced from the Big Snowy group on the Devil's Basin anticline, where the "Van Dusen sand," an oölitic limestone near the top of the Otter formation, yielded approximately 20,000 barrels of black low-gravity (24.7 Baumé) oil between 1919 and 1937. On the Baker-Glendive anticline several wells encountered showings of oil within the Charles, and oil up to 150 barrels per day has been produced with some water from a zone which, depending on interpretation, is at the base of the Charles or the top of the Madison. Elsewhere, drilling on favorable structure through the Big Snowy group failed to reveal the presence of oil.

Although the limited number of wells drilled through the Big Snowy group is inadequate to condemn these sediments as potential reservoirs, the results appear discouraging; however, no tests have been drilled where favorable conditions in the Heath formation are to be expected. It has been noted that the sandstones of the Heath formation are thickest and coarsest in grain-size in the proximity of the ancestral Sweetgrass arch, and that they become progressively thinner and finer in grain-size on the east and south, where most of the existing tests have been drilled. Moreover, where the favorable conditions of porosity and permeability in the Heath sandstones are to be expected, these sandstones are overlain with angular unconformity by impervious sediments of the Ellis, thus fulfilling a basic requirement for a stratigraphic trap. When these conditions are considered in conjunction with abundance of organic shales interbedded with the sandstones in the Heath, it seems that further testing of the Big Snowy group in the area extending northeast from the Big Snowy Mountains might possibly be warranted.

In central Montana relatively shallow wells drilled into the Kibbey formation yielded large volumes of water, indicating favorable conditions of porosity and permeability in that area. Although predictions about the character of the Kibbey are hazardous, because of its variable nature, the Kibbey can not be eliminated as a possible petroleum reservoir, particularly in those areas where it lies disconformably on the Madison.

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OCCURRENCES AND TYPES OF CRUDE OILS IN ROCKY MOUNTAIN REGION[1]

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ABSTRACT

The application of correlation index numbers to analyses of Rocky Mountain crude oils indicates that these oils can be grouped into six major and four intermediate types, which correlate rather well with certain geologic systems and geographical areas. The oil fields are listed alphabetically by states in one tabulation, which shows all productive zones, all producible wells in each zone, production statistics, and other data. In another tabulation the oil fields are similarly arranged by geologic systems, showing the correlation index numbers and other properties of the oils. The occurrences and types of oil are discussed briefly, and diagrams illustrate the correlation indexes of representative analyses.

INTRODUCTION

Harold M. Smith,[4] working with the Tulsa Geological Society research committee, has evolved a practical method of comparison in which differences, as well as similarities, in crude oils are emphasized. The writers have applied these indexes to more than 400 analyses of crude oils in the Rocky Mountain region, and the similarities and differences found are the basis of this paper. The study was suggested by the work of the committee, which has applied the correlation index numbers since 1938.

The need for more complete information regarding occurrences and characteristics of crude oils in the Rocky Mountain region prompted the inclusion herein of relevant data on 133 oil fields, and correlation indexes and other properties of 216 oil samples. The paper is largely factual and allows the reader to draw his own conclusions as to the origin and relative importance of the crude oils.

To avoid repetition herein, the reader is referred to maps, geologic correlation charts, and Hempel analyses in the publications here cited.[5] Unless otherwise stated, the analyses were made in the Casper (formerly Midwest), Wyoming, laboratory of the Geological Survey. The other data are from information available in the Casper office of the Survey.

[1] Published by permission of the director of the Geological Survey. Manuscript received, March 17, 1943.

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[3] Petroleum engineer, Geological Survey, United States Department of the Interior.

[4] Harold M. Smith, "Correlation Index to Aid in Interpreting Crude-Oil Analyses," *U. S. Bur. Mines Tech. Paper 610* (1939).

[5] James G. Crawford, "Oil-Field Waters of Wyoming and Their Relation to Geological Formations," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 7 (July, 1940), pp. 1214–1329.
———, "Oil-Field Waters of Montana Plains," *ibid.*, Vol. 26, No. 8 (August, 1942), pp. 1317–74.
C. E. Dobbin, "Structural Conditions of Oil and Gas Accumulation in Rocky Montain Region of United States," *ibid.*, Vol. 27, No. 4 (April, 1943), pp. 417–78.
Ralph H. Espach and H. Dale Nichols, "Petroleum and Natural-Gas Fields in Wyoming," *U. S. Bur. Mines Bull. 418* (1941).
———, "Crude Oil Analyses, Rocky Mountain Fields," *U. S. Geol. Survey* (1940). A mimeographed publication containing, with annual supplements, about 250 Hempel analyses, many of which are used in this paper.

The area covered embraces Colorado, Montana, Utah, and Wyoming, where most of the commercial oil deposits of the Rocky Mountain region have been found. Northwestern New Mexico is usually included in this region, but information and crude-oil samples were not available to the writers.

The oil fields and analyses have been classified under four geologic systems: Tertiary, Cretaceous, Jurassic, and pre-Jurassic, according to the characteristics of the strata and the crude oils. For purposes of brevity and convenience, oil fields, areas, traps, and pools are hereinafter referred to as "fields," and crude oils or natural liquid petroleums as "oils." Emphasis is placed upon the stratigraphic occurrences rather than the structural.

ACKNOWLEDGMENTS

The writers are indebted to H. J. Duncan of the Geological Survey for general supervision of this study; to the petroleum engineers and other associates in the Survey for valuable assistance in obtaining the oil samples and field data; to C. E. Dobbin for critical review of the manuscript; to others in the oil industry whose informal suggestions and material have been helpful; and to J. W. Jones of the Survey for preparing the illustrations.

CORRELATION INDEX NUMBERS

Crude oil is essentially a complex mixture of saturated hydrocarbons of the paraffine, naphthene, and aromatic series, and does not lend itself easily to separation into distinct groups. Oils have been classified as light or heavy, according to gravity; sweet or sour, according to sulphur content; green or black, according to color; and various other loosely applied terms according to some physical property. The average oil man is accustomed to the "base" classification, wherein the oils were originally classified as paraffine, mixed, or asphalt.

After the accumulation of a large number of Hempel analyses, Smith,[6] in 1927, classified oils under four bases, namely, paraffine, intermediate, naphthene, and hybrid. In 1935 Lane and Garton[7] increased the number of bases from four to nine in an effort to classify all oils more precisely.

There is merit in these "base" classifications, but there are also many disadvantages. Many paraffine-base oils contain considerable amounts of the naphthenes, and naphthene-base oils ordinarily contain asphaltic material and paraffine wax. Thus, the names are misleading. Then, too, the divisions are so broad that two oils in the same "base" classification may be radically dissimilar.

In order to compare oils throughout the entire range of their distillation fractions, Smith,[8] in 1939, introduced correlation index numbers based on average boiling-point and specific-gravity characteristics of the distilled fractions. Smith says:

[6] N. A. C. Smith, "The Interpretation of Crude Oil Analyses," *U. S. Bur. Mines R. I. 2806* (1927).

[7] E. C. Lane and E. L. Garton, "Base of a Crude Oil," *U. S. Bur. Mines R. I. 3278* (1925).

[8] Harold M. Smith, *op. cit.*

The correlation index is a number whose magnitude indicates certain characteristics of a crude-oil distillation fraction. If a fraction were composed exclusively of normal paraffin hydrocarbons, the value of the index number would be zero. If the fraction be from a paraffin base crude-oil of the usual type, its index will not be zero but will be small, while fractions from intermediate and naphthene base crudes will have increasingly greater values for the indexes.

Smith points out that the index value obtained represents the average characteristics of the fraction in comparison with a normal paraffine hydrocarbon of the same boiling point, and it should not be construed to mean that the fraction consists predominantly of a hydrocarbon having the same specific gravity and boiling point. In general, he says, fractions with index values from 0 to 15 are almost certain to be predominantly paraffinic; values from 15 to 50 indicate naphthenes or different mixtures of paraffines, naphthenes, and aromatics; and values above 50 indicate that aromatic rings probably predominate.

The indexes by Smith were based on average boiling points obtained at Bartlesville, Oklahoma, with a barometric pressure of about 746 mm. of mercury. The samples listed in this paper, except for a few not available to the Survey laboratory, were analyzed at an average barometric pressure of 635 mm. of mercury. Because of the lower barometric pressure, each fraction therefore contained higher-boiling material and the correlation indexes used by Smith are not strictly applicable. It was realized that satisfactory comparisons might be made on the basis of these values, but it was thought that the block diagrams might be somewhat misleading due to the fact that they would be displaced to some extent. Accordingly, the average boiling points were corrected for altitude and the corrected figures substituted in the correlation index equation. The indexes thus determined averaged two to three numbers higher for fractions 1 to 11, and are given in their entirety in the appendix.

It should be emphasized that these indexes can be used for comparing crude oils analyzed by the Bureau of Mines Hempel method within 10 or 20 mm. of the 635-mm. pressure base used herein, but they should not be used for comparing oils analyzed under widely different pressures.

TYPES OF OIL

Oils in the Rocky Mountain region range in gravity from 75° to 11° A. P. I. (0.68 to nearly 1.00 specific gravity); the oils vary in color from clear to glossy black through various shades of amber, green, and brown; some oils are solid at 90°F. and other oils are liquid at −50°F.; and the sulphur content varies from only a trace to more than 4 per cent. Despite the seemingly complex physical and chemical differences among the oils, the analyses—216 of which are tabulated and 40 illustrated in this paper—indicate that they can be grouped into six fairly well defined types and four intermediate types.

Type I is represented by 3 analyses from Tertiary deposits at Hiawatha (East) and Powder Wash, Colorado, and Northern Hiawatha, Wyoming, and is

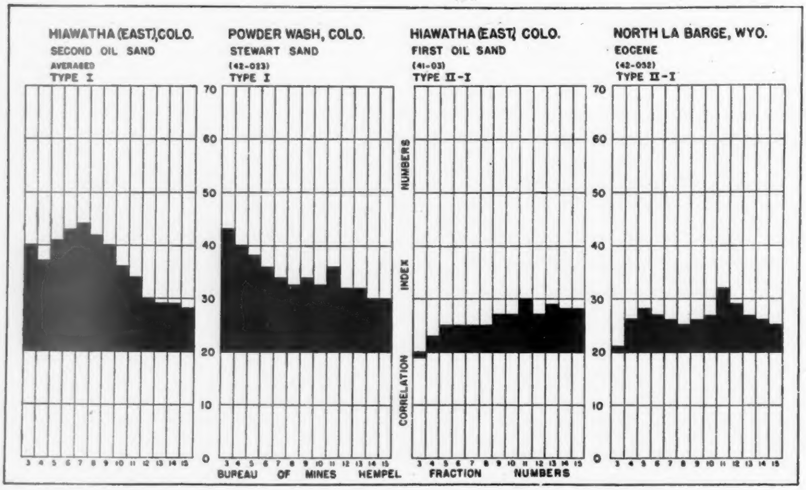

FIG. 1.—Representative Type I and Type II-I oils of Rocky Mountain region.

illustrated in Figure 1. The index graph starts near index number 40 and drops to 30, like an upset curve, because the ordinary oil consists of fractions of increasing indexes. These oils are of intermediate-paraffine base, are green in color, and have a negligible sulphur content, but have high pour points, ordinarily

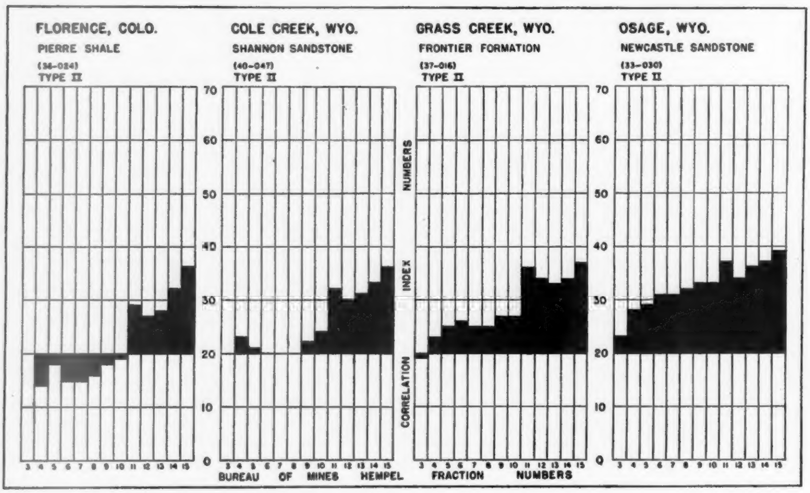

FIG. 2.—Representative Type II oils of Rocky Mountain region.

ranging from 70° to 90°F. At temperatures above their pour point they are very fluid and have low Saybolt viscosities. They range in gravity from 36° to 38° A. P. I., and contain 15 to 35 per cent gasoline. The index graph indicates that cyclic compounds (probably naphthenes) predominate in the low- and medium-boiling fractions, and paraffines in the higher. The cyclic compounds in the gasoline fractions (numbers 3 to 7) point to a straight-run product of higher than average octane number. Considerable wax can be expected in the higher-boiling fractions.

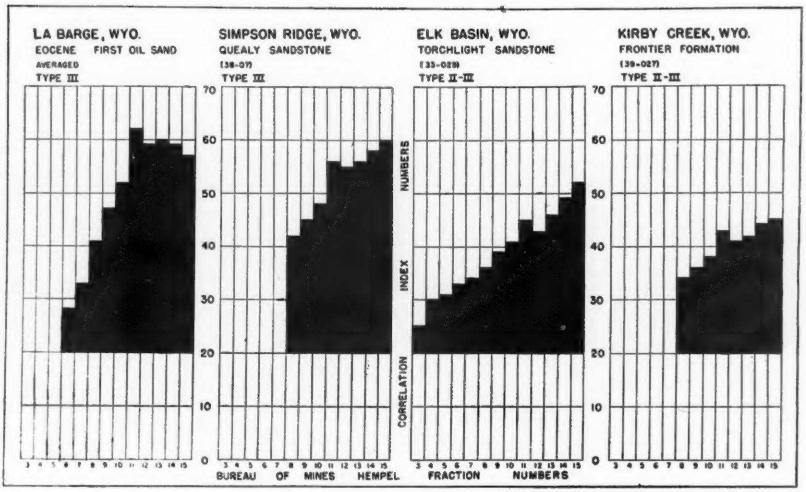

FIG. 3.—Representative Type III and Type II-III oils of Rocky Mountain region.

Type II is represented by 84 analyses and is the type of oil found in most Cretaceous and Jurassic deposits in Colorado and Wyoming. It is illustrated in Figure 2. Two pre-Jurassic oils from Utah and 6 from Lance Creek, Wyoming, also are of this type. The index graph starts with an index number between 15 and 25 and progresses upward to a number between 25 and 40, seldom higher. This type includes many of the paraffine-base and intermediate-base oils, and nearly all of these oils are green in color, with a low sulphur content, low viscosity, low carbon residue, and pour points ranging from below 5°F. to 65°F. The gravity range is from 28° to 52° A. P. I. and averages 37°F.; the gasoline content ranges from 15 to 60 per cent. The index graphs vary considerably in the low-boiling fractions, many of them being definitely paraffinic, others containing a greater proportion of naphthenes; but the medium- and high-boiling fractions are in reasonably close agreement, consisting of both naphthenes and paraffines in which neither dominates to any great extent. Aromatics are absent, or present only in very small

proportions in the higher-boiling fractions. The octane rating of straight-run gasolines from these oils is ordinarily low, but they are good refining stock and are particularly suitable for cracking.

Type III is represented by 15 analyses from Tertiary deposits at La Barge, Brenning Basin, and Shawnee, Wyoming, and Cretaceous deposits at Wellington, Colorado, Mosser Dome, Montana, and eight small fields in Wyoming. It is illustrated in Figure 3. Fractions below 6 are ordinarily absent or so small in quantity that they have been combined, but when present they may have indexes

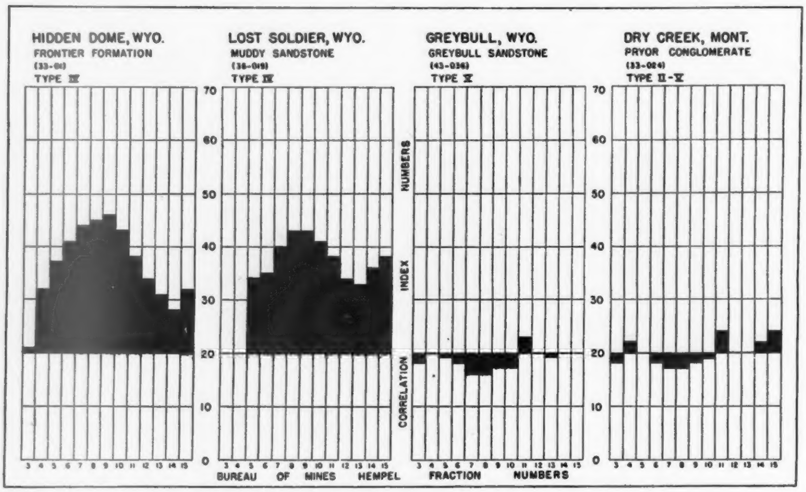

FIG. 4.—Representative Type IV, Type V, and Type II-V oils of Rocky Mountain region.

as low as 15; the indexes for fraction 15 are ordinarily between 50 and 70, sometimes above 70. These oils are further characterized by a low sulphur content and a green color, which differentiates them from Type VI oils with which they may be confused. Type III oils are of intermediate, intermediate-naphthene, naphthene-intermediate, and naphthene base, with a gravity range of 17° to 33° A. P. I. The gasoline content varies from 0 to 28 per cent, and the oils are ordinarily rather viscous. Although the low-boiling fractions, when present, are paraffinic, the medium-boiling fractions become rapidly more cyclic, naphthenes predominating, and aromatics are indicated by the high index numbers of fractions 11 to 15. Though little gasoline is obtained from most of these oils, the octane rating is ordinarily high, because of the cyclic content. The oils are valuable for their lubricating content, as many of these products are wax-free.

Type IV is represented by 7 analyses from Cretaceous deposits at Hidden Dome, and Cretaceous and Jurassic deposits at Lost Soldier, Wyoming, and is

illustrated in Figure 4. The index graph is in the form of an arch with maximum indexes occurring at fractions 8 and 9 and minimum indexes at 3, 4, 5, 13, 14, and 15. These oils are of intermediate to intermediate-paraffine base with a sulphur content ranging from 0.15 to 0.36 per cent. Gasoline content of the 43° A. P. I. Hidden Dome oil averages 45 per cent, and that of the 28° to 31° A. P. I. Lost Soldier oil varies between 8 and 15 per cent. Cyclic compounds predominate in the low- and medium-boiling fractions, and the high-boiling fractions contain sufficient paraffinic material to prevent the dominance of the naphthenes. These

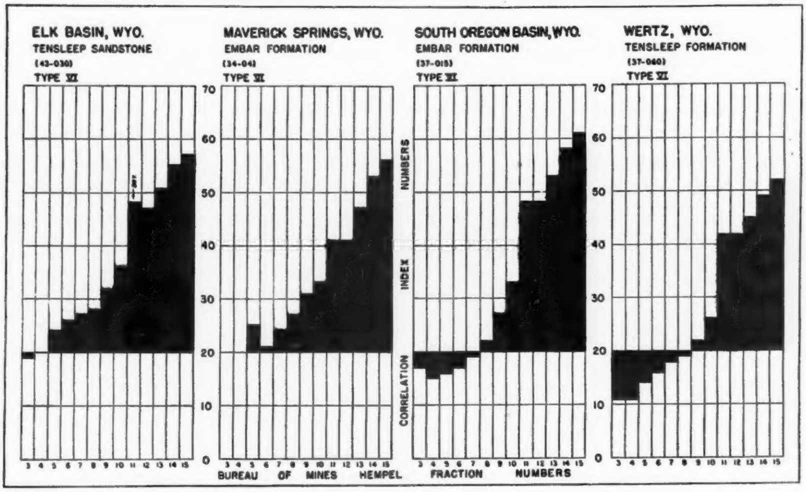

FIG. 5.—Representative Type VI oils of Rocky Mountain region.

oils are the most valuable from the standpoint of refining in the Rocky Mountain region. The cyclic compounds in the gasoline fraction result in a product of high octane rating, and the paraffinic characteristics of the high-boiling fractions make a good cracking stock.

Type V is represented by 5 analyses from Cretaceous deposits at Lake Basin, Montana, North McCallum, Colorado, and Greybull, Wyoming, and Jurassic deposits at Big Medicine Bow, Wyoming, and is illustrated in Figure 4. These oils are definitely paraffinic throughout their entire range, and in their best examples the index numbers are mainly below 20. They have a paraffine base, negligible sulphur, and are among the highest gravity oils in the Rocky Mountain region, ranging from 63° to 75° A. P. I. at Big Medicine Bow to 44° at Lake Basin. Gasoline content varies from 80 per cent at Big Medicine Bow to 32 per cent at Lake Basin, and is roughly proportional to the pour point, those oils containing the most gasoline having pour points far below zero, and those con-

taining the least gasoline having pour points as high as 80°F. at Lake Basin. At temperatures above their pour points, the oils are very fluid and have a low Saybolt viscosity. The preponderance of aliphatic hydrocarbons indicates that the gasolines will have a low octane rating, and the high-boiling fractions are ordinarily small and waxy. Therefore, these are not considered good refining oils.

Type VI is represented by 66 analyses from Jurassic deposits at Bolton Creek, Poison Spider, Spindletop, and Steamboat Butte, Wyoming, and from pre-Jurassic deposits at Soap Creek, Montana, and in most of the Wyoming fields.

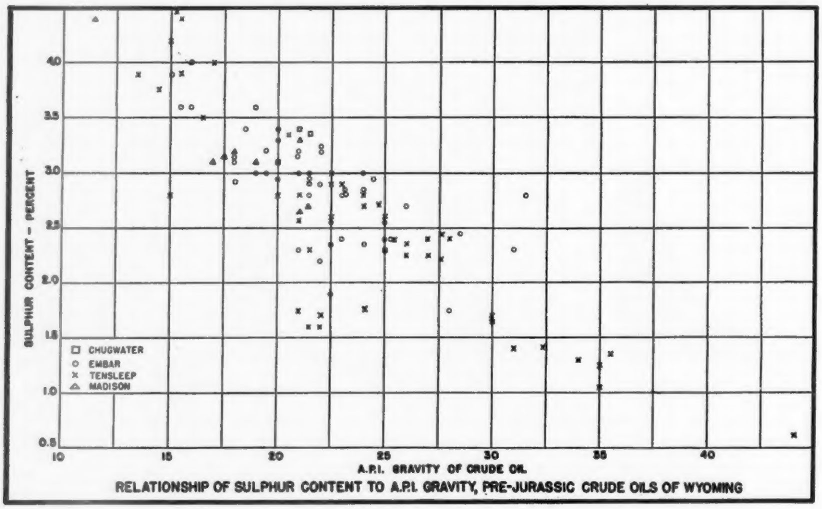

FIG. 6.—Relationship of sulphur content to gravity in pre-Jurassic oils of Wyoming.

It is illustrated in Figure 5. The index graph starts with indexes of 15 to 25, and continues with moderate indexes until fraction 11 is reached, at which point the index numbers rapidly increase to a final high of 55 to 70. These oils are of paraffine-intermediate and intermediate base, ordinarily black or brownish black in color, and include the so-called black or heavy oils of Wyoming, although a few of the higher-gravity oils of this type are classified as light. Gravities range from a low of 11° A. P. I. at Red Springs, Wyoming, to a high of 35° in the fields of the Sweetwater Basin of Wyoming, and gasoline content varies from 0 to 30 per cent. Viscosities vary from a low of 40 seconds to a high of more than 6,000 seconds, the high-gravity oils being of low viscosity, those oils below 30° A. P. I. becoming increasingly viscous. Pour points are ordinarily below 5°F., although some of the more viscous oils have pour points as high as 30°F. Asphaltic material is present in quantities from 5 to 40 per cent. The index graph indicates low- and medium-boiling fractions in which paraffines predominate, but cyclic compounds

become increasingly important from fraction 7 on and predominate in the higher-boiling fractions. Aromatics are ordinarily present in the high-boiling fractions, and dominate these fractions in some of the oils. The high-gravity oils of this type are refined by the usual methods by blending with sweet oil; the low-gravity oils, because of the corrosive effect of the sulphur, are not amenable to the usual refining methods, but are topped for their yield of fuel and road oil.

Type VI oils are characterized by the presence of sulphur in definite and appreciable amounts, ranging from 1.0 per cent to 4.5 per cent, except for one oil from Pine Mountain, Wyoming, in which the sulphur content has been found to be as low as 0.17 per cent. At least part of the sulphur is in the form of hydrogen sulphide, and both water and gas associated with these oils also contain hydrogen sulphide. One of the striking features of Type VI oil is the relationship existing between gravity and sulphur content, illustrated in Figure 6. It is not a straight-line function, but a gentle concave curve drawn through the points of greatest frequency indicates the approximate relationship. It is possible from this curve to estimate roughly the probable sulphur content of a Type VI oil when its gravity is known. All these oils, except the Pine Mountain oil and the two Type VI oils in the addenda of Table II, are plotted on this graph.

If the index numbers of the same type oil are examined critically it will be noted that there is considerable variation between them. In some instances the index numbers of the low-boiling fractions are higher or lower than the average and the high-boiling fractions are relatively unaffected; in other instances the converse is true. In some cases the magnitude of all the index numbers is higher or lower than the average. These variations may, in part, be due to methods of sampling, minor analytical errors, or changes in barometric pressure between analyses. In critical studies of oil analyses from the same sand of a field, the writers have found that the structural position from which a sample is obtained influences the magnitude of the index numbers, particularly in the low-boiling fractions. The writers have reason to believe that gas and water associated with the oil influence the index number, and doubtless there are other unrecognized factors. For these reasons, they have chosen to ignore variations in magnitude of individual fractions, and have based their type classifications on the general trend of the index numbers, together with the sulphur content of the oil.

These factors, the writers believe, may have so modified some oils that intermediate types were found necessary to classify them. Types II-I, II-III, II-V, and II-VI were introduced for this reason, the first three being relatively unimportant.

Type II-I is represented by 6 analyses from Tertiary deposits at Powder Wash and Hiawatha (East), Colorado, and La Barge and North La Barge, Wyoming, and is illustrated in Figure 1. The index graph begins near 20 and ends at 30 or lower. If a Type I graph be compared with a Type II-I graph, it will be found that the differences are greatest in the low- and medium-boiling

fractions, and become negligible in the high-boiling fractions. These oils are of paraffine base with only a trace of sulphur, and are ordinarily higher in gravity than the Type I oils.

Type II-III is represented by three analyses from Cretaceous deposits at Elk Basin (south end) and Kirby Creek, Wyoming, and is illustrated in Figure 3. The index graph is similar to that of Type II but the index numbers are from 5 to 15 values higher. While the usual Type II oils from the main part of the Elk Basin field have a sulphur content of less than 0.1 per cent, the Type II-III oils

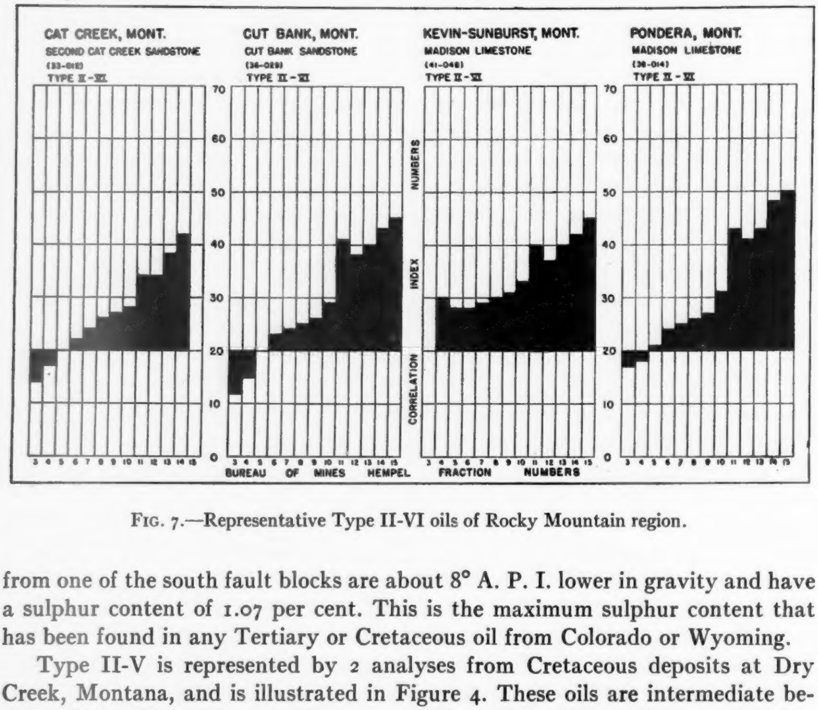

FIG. 7.—Representative Type II-VI oils of Rocky Mountain region.

from one of the south fault blocks are about 8° A. P. I. lower in gravity and have a sulphur content of 1.07 per cent. This is the maximum sulphur content that has been found in any Tertiary or Cretaceous oil from Colorado or Wyoming.

Type II-V is represented by 2 analyses from Cretaceous deposits at Dry Creek, Montana, and is illustrated in Figure 4. These oils are intermediate between Types II and V, trending more to Type V, and the indexes end with a magnitude of 24. These oils average about 50° A. P. I. gravity, contain only traces of sulphur, and, like the ordinary Type V oils, are of paraffine base.

Type II-VI is represented by 25 analyses from deposits of three systems in Montana, one pre-Jurassic deposit in Wyoming, and the only pre-Jurassic deposit in Colorado. It is illustrated in Figure 7. The index graph begins with a magnitude of 15 to 25, comparable with a Type II graph, and ends between 45 and 55, somewhat higher than a Type II graph, but not as high as a Type VI graph. It may resemble a Type II graph, a Type VI graph, or be intermediate between

them. This type contains definite quantities of sulphur, between 0.2 and 1.8 per cent, but the proportion of sulphur content to gravity is considerably less than in the Type VI oils previously discussed. These oils vary in gravity from 22° to 50° A. P. I., and average about 36°. From the standpoint of the light-oil refiner they are almost as valuable as Type II oils, but special precautions must be taken in most cases to prevent sulphur corrosion.

The writers do not imply the same or different sources for these types of oil. Types I to V occur principally in sandstones which are in contact with shale bodies that could have been the source of the oil. Type VI occurs principally in older sandstone beds in contact with limestones, or in the limestones themselves. Type II-VI occurs in both sandstones in contact with shale, and in limestones.

A summary of the occurrences of the types of oils for which analyses are available is as follows.

	I	*II*	*III*	*IV*	*V*	*VI*	*II-I*	*II-III*	*II-V*	*II-VI*	*Total*
Tertiary											
Colorado	2						3				5
Wyoming	1		5				2				8
Cretaceous											
Colorado		13	1		1						15
Montana			1		1				2	15	19
Wyoming		51	8	5	1		1	3			69
Jurassic											
Colorado		5									5
Montana										1	1
Wyoming		7		2	2	4					15
Pre-Jurassic											
Colorado										1	1
Montana						2				7	9
Utah		2									2
Wyoming		6				60				1	67
Totals	3	84	15	7	5	66	6	3	2	25	216

Some probabilities may be drawn from this summary: (1) Type I, II-I, or III oil will be found in Tertiary deposits; (2) Type II oil will be found in Cretaceous deposits; (3) Type VI oil will be found in pre-Jurassic deposits of Wyoming; and (4) Type II-VI oil will be found in deposits in Montana, except near the Wyoming border.

FIELD AND CRUDE-OIL TABULATIONS

Table I lists alphabetically by states all the fields that have produced oil, are now producing, or are shut-in, including several of semi-commercial importance because of their possible prospective value and previous references to them in maps and literature. Their relative importance may be judged by the well and production figures. Minor oil showings have not been included. Some fields produce only oil, some both oil and gas; some produce from only one formation, and a few from as many as 11 separate zones. Dry gas fields and wells have been disregarded, except in the total well count under those fields also producing oil.

Data included are (1) legal location, which is generally restricted to the pro-

ductive area, if less than the entire structural closure; (2) productive zone, with formation and member or local name, if any; (3) writers' type classification of the oil; (4) number of producible wells in each formation as of December 31, 1942,[9] and total number drilled; (5) oil production for 1941, 1942, and total accumulated production; (6) year of first production for which statistics are available, or discovery date if field has remained shut-in; (7) deepest formation reached by the drill and total depth of the well, which is usually the greatest depth reached, although structural and stratigraphic position have been considered insofar as practicable.

Table II has the same fields arranged under the four geologic systems so that ready reference may be made to the occurrences of oil therein, and includes the following data: (1) productive zone; (2) writers' type classification of the oil; (3) correlation index numbers from fraction 3 through fraction 15; (4) A. P. I. gravity; (5) percentage of sulphur (by Parr peroxide bomb); (6) Saybolt Universal viscosity at 100°F.; (7) percentage of carbon residue (which, when multiplied by 2.5, gives the approximate percentage of asphalt in the oil); (8) percentage of straight-run gasoline (which will approximate the percentage of 419°F. end-point gasoline obtained by standard refining methods); (9) base of the oil; (10) laboratory sample number.

Table II also contains for comparative purposes analyses of so-called separate "sands" or members, such as the First, Second, and Third Wall Creek sandstone members of the Frontier formation at Salt Creek, Wyoming; and the Converse, the First, Second, Third, and Fourth Leo and the Bell members of the Minnelusa formation at Lance Creek, Wyoming.

TERTIARY OILS

Tertiary oils are represented by 5 samples from Colorado and 8 from Wyoming.

The main Tertiary production has been from the La Barge field in southwestern Wyoming, which has produced about 8,000,000 barrels of oil. The Hiawatha (East) and Powder Wash gas fields in northwestern Colorado (the Hiawatha field extends into Wyoming) are relatively recent in oil production but ultimately may yield a similar amount of oil. The Northern Hiawatha and North La Barge areas have been separated from the main pools by unitization or definition. Two areas of minor importance, except as to conjecture as to the source of the oil and the possibility of a greater accumulation near by, are at Brenning Basin and Shawnee, the former west and the latter east of Douglas in east-central Wyoming. These small occurrences were found in the lacustrine White River formation of Oligocene age, lying unconformably on older beds.

The oil sands at La Barge originally were assumed to be in the Almy forma-

[9] It should be emphasized that this count includes both active producing wells and shut-in wells, and may vary somewhat from that of other sources because of current changes, shut-in, and gas-injection wells; the Geological Survey considers a well producible if it is still capable of some production and has not been definitely abandoned.

tion of the Wasatch group as classified by Schultz[10] and are still commonly considered to be Wasatch. Three lenticular oil sands below a water sand are now fairly well identified in the main La Barge field, and are numbered 1, 2, and 3, for identification herein. However, W. B. Kramer, of the United States Geological Survey, in an unpublished map of the North La Barge and Piney-La Barge (Dry Piney) unit areas, has assigned the sands to the Eocene (?) older than Wasatch. H. D. Thomas, of the University of Wyoming, in sample identifications for J. A. Minton of the Wasatch Production Company, has found marine Cretaceous fossils (*Ostrea*) in cores from the basal oil sand at North La Barge. Due to the La Barge overthrust fault many of the wells begin in the Hilliard shale of Cretaceous age, enter the Eocene (?) with its lenticular sands, and may reach the Hilliard again.

The oil sands at Hiawatha (East) and Powder Wash, Colorado, have been assigned to the Hiawatha member of the Wasatch formation (lower Eocene) by Nightingale.[11] Three lenticular oil sands occur in wells in the southeastern part of the Hiawatha (East) gas field at depths between 2,032 and 2,512 feet, of which the middle sand is the principal producer. These sands have been numbered 1, 2, and 3 for identification in this paper. At Powder Wash, Nightingale has called an oil sand at 3,087–3,113 feet the Stewart sand, and one at 5,014–5,032 feet in another well the Allen sand, the names being derived from the leaseholders.

CRETACEOUS OILS

Cretaceous oils are represented by 15 samples from Colorado, 19 from Montana, and 69 from Wyoming.

The Colorado and Wyoming oils are mainly of Type II and those of Montana Type II-VI. These are the most common light oils of the refiner. Cretaceous beds have yielded about 66 per cent of all the Colorado oil, 55 per cent of all the Montana oil, and 74 per cent of all the Wyoming oil. Fields that have produced more than 5,000,000 barrels of oil from the Cretaceous rank as follows: Salt Creek, Cut Bank, Big Muddy, Grass Creek, Rock Creek, Cat Creek, Florence, Lost Soldier, Elk Basin, Osage, and Wellington. On the basis of ultimate production they will probably rank about the same, but Teapot, Dry Creek, Cole Creek, Quealy, and possibly other fields, may enter the list. The estimated ultimate production of the Cut Bank field will increase considerably the percentage of Montana oil obtained from the Cretaceous.

In Colorado, the Pierre and Mancos shales account for more than half the Cretaceous oil produced, and the Dakota group for the remainder. The Upper Dakota of this paper is the "Muddy" sand of the drillers in some fields, and may or may not be the equivalent of the Muddy sand of Wyoming.

[10] A. R. Schultz, "Geology and Geography of a Portion of Lincoln County, Wyoming," *U. S. Geol. Survey Bull. 543* (1914).

[11] W. T. Nightingale, "Geology of Vermilion Creek Gas Area in Southwest Wyoming and Northwest Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 8 (August, 1930), pp. 1013–40.

In Montana some Cretaceous oil occurs near the base of the Colorado shale in the Cat Creek and Whitlash fields, and other stray occurrences have been noted. The major Cretaceous production is from the Kootenai formation in the northwestern part of the state. In south-central Montana some production has been found in the Frontier and Cloverly formations.

In Wyoming, very little Cretaceous oil occurs above the Frontier formation, although the Shannon sandstone is the major producer at Cole Creek, and there are small occurrences in other fields. The Frontier formation, with its Wall Creek sandstones, is the main producer. Oil below the Frontier occurs in the Mowry, Thermopolis, Cloverly, and corresponding formations. The Muddy sand here is assigned to the Thermopolis shale and is the approximate equivalent of the Newcastle sand of the Graneros shale in northeastern Wyoming. The Cloverly formation is of Lower Cretaceous age and contains the sands commonly called Dakota and Lakota in most of Wyoming and southern Montana, although the true Dakota sandstone is of Upper Cretaceous age. The Geological Survey calls these sandstone members Greybull and Pryor in northwestern Wyoming and south-central Montana, and in eastern Wyoming the Fall River sandstone of the Geological Survey is commonly called "Dakota," and is underlain by the Fuson shale and Lakota sandstone.

JURASSIC OILS

Jurassic oils are represented by 5 samples from Colorado, 1 from Montana, and 15 from Wyoming.

Type II oil again predominates in Colorado and Wyoming, although an exceptional feature is the occurrence of Type VI oil in the Sundance formation at Bolton Creek, Poison Spider, Spindletop, and Steamboat Butte, Wyoming. (Some geologists assign the new discovery at Steamboat Butte to the Chugwater (?).) Type II-VI predominates in Montana. Jurassic beds have yielded about 33 per cent of all the Colorado oil and 8 per cent of all the Wyoming oil. The writers have assigned the oil from the Ellis-Madison contact in Montana to the pre-Jurassic Madison limestone, thus limiting the Jurassic oil in that state to small amounts in stray sands of the Ellis at Kevin-Sunburst and to the Emrick sand in the abandoned Bannatyne field, although the Ellis has been considered as the probable source of much of the oil in the Sweetgrass Arch region.[12]

Fields that have produced more than 5,000,000 barrels of oil from the Jurassic rank as follows: Lance Creek, Iles, Lost Soldier, and Salt Creek. The relatively new Wilson Creek field may eventually outrank most of these fields and considerably increase the percentage of oil in Colorado produced from Jurassic beds.

Most of the Jurassic oils of Colorado and Wyoming occur in the Sundance formation, but some is found in the overlying Morrison formation. It is usual, where both the Sundance and Morrison contain oil, to find the Sundance the

[12] C. E. Dobbin and C. E. Erdmann, "Geologic Occurrence of Oil and Gas in Montana," *Problems of Petroleum Geology* (Amer. Assoc. Petrol. Geol., 1934), p. 717.

larger and more prolific producer; but at Wilson Creek, the Morrison pool considerably exceeds the Sundance.

PRE-JURASSIC OILS

Pre-Jurassic oils are represented by 1 sample from Colorado, 9 from Montana, 2 from Utah, and 67 from Wyoming.

Type II-VI predominates in Montana and Type VI in Wyoming. Type II and Type II-VI oils are included among the light oils, and Type VI oils are ordinarily among the heavy oils, but this is not a definite criterion because gravity, sulphur content, and other properties are often considered. Of the Wyoming pre-Jurassic oils, East Mahoney, Lance Creek, Lost Soldier, Mahoney (West), Wertz and possibly Elk Basin are considered to be light oils because of their type or higher than average gravity.

Pre-Jurassic deposits have yielded all of the minor production of Utah, about 44 per cent of the production of Montana, and 18 per cent of that of Wyoming. One pre-Jurassic well in the Rangely field, Colorado, has not been produced commercially. Fields that have produced more than 5,000,000 barrels of oil from the pre-Jurassic rank as follows: Kevin-Sunburst, Lance Creek, North and South Oregon Basin, Garland, Frannie, Wertz, Pondera, Hamilton Dome, Byron, and Lost Soldier. On the basis of ultimate production, Elk Basin, Grass Creek, Maverick Springs, Salt Creek, and other fields, may become included, and the rank of these fields may change. Production has been irregular in the past, and has been dependent to a great extent on the accessibility of the field, quality and price of the oil, and market demand for fuel and road oil.

The pre-Jurassic oil occurrences may be summarized as follows. Minor oil production has been found in the Chugwater redbeds (Triassic and Permian) in five fields in Wyoming. The Moenkopi formation (Lower Triassic) and Rico formation (Permian) account for the two small fields in Utah. Embar (Lower Triassic and Permian) production occurs in most of the black oil fields of the Big Horn and Wind River basins, Wyoming, and in three fields outside these basins, and accounts for much of the pre-Jurassic production therein. The Tensleep sandstone (Pennsylvanian) is productive in many of the fields in these two basins and also in central Wyoming, particularly in the Lost Soldier-Wertz-Mahoney area. The Minnelusa sandstone (Pennsylvanian) is the major producer at Lance Creek, and has also yielded oil in four small areas in northeastern Wyoming. The main occurrence of oil in the Amsden formation (Pennsylvanian) is at Soap Creek, Montana, and probably South Spring Creek, Wyoming, although the formation may be exposed and have some saturation in wells in other fields. The Weber quartzite (Pennsylvanian) accounts for the only pre-Jurassic oil in Colorado, and the Quadrant or Heath formation (mainly Upper Mississippian) for one small field in central Montana. The Madison limestone (Upper Mississippian) is the main producing formation at Kevin-Sunburst, Pondera, and Twin Rivers (Reagan), Montana, and also yielded oil in non-commercial

amounts in the Cedar Creek (Baker-Glendive) deep wells. In Wyoming, it has been found productive only in the Frannie, Garland, Oregon Basin, and Red Springs fields in the Big Horn basin. The Bighorn dolomite (Upper Ordovician) also carried some oil at Cedar Creek, Montana, and, in the opinion of some geologists, the lower part of the productive zone at Garland should be assigned to the Bighorn rather than to the Madison.

APPLICATION OF INDEXES TO FIELDS

Figures 8 to 11 are included to illustrate the characteristics of some of the individual oils from three of Wyoming's most important fields. The Lance Creek

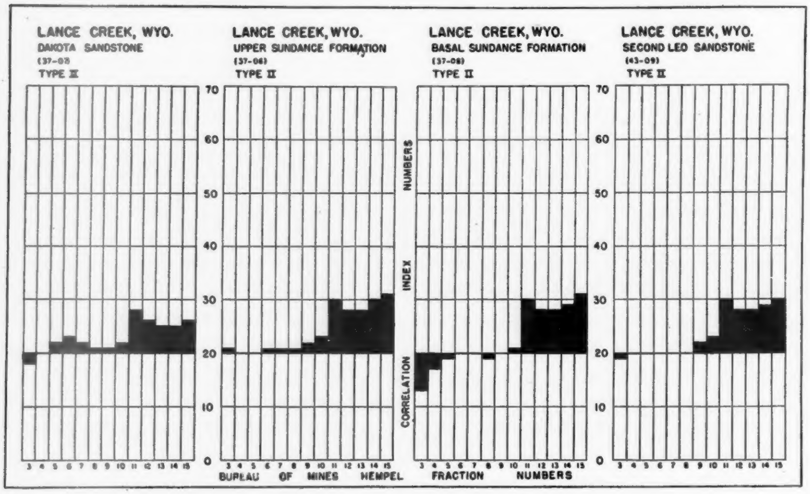

FIG. 8.—Index graphs of representative Lance Creek oils.

field has had the largest yearly production since 1939; the Salt Creek field has the largest accumulated production; and the Lost Soldier field is currently the next most important multiple-horizon field.

Lance Creek field.—The Fall River (Dakota), Sundance, and Minnelusa formations include the eight or more productive zones for which separate samples are given in Table II. The Frontier, Muddy, and Lakota sands produced a minor amount of oil early in the field's history. The so-called Dakota-Lakota group has several benches, the Sundance has two, and the Converse, four Leo members, and the possible Bell sand, are distinguished in the Minnelusa, the major productive zone.

The correlation indexes indicate that all the oils are nearly identical in composition. They differ somewhat in gravity and other physical characteristics, but

the differences are not marked. The Dakota oil has the fewest points of similarity. All of the Leo oils are similar, indicating rather strongly intercommunication of the different sands. The Converse sand (upper Minnelusa) oil is similar to the Leo oils, but there are enough dissimilar points to warrant the conclusion that the Converse sand does not communicate with the Leo sands. The notable feature is the fact that these Minnelusa oils are the only Type II pre-Jurassic oils in the state. These facts suggest that they are from the same source and that the source beds are probably Cretaceous or Jurassic shales, which were brought into contact with the Minnelusa formation by faulting.

Lost Soldier field.—The Lost Soldier field produces oil from eleven zones, as

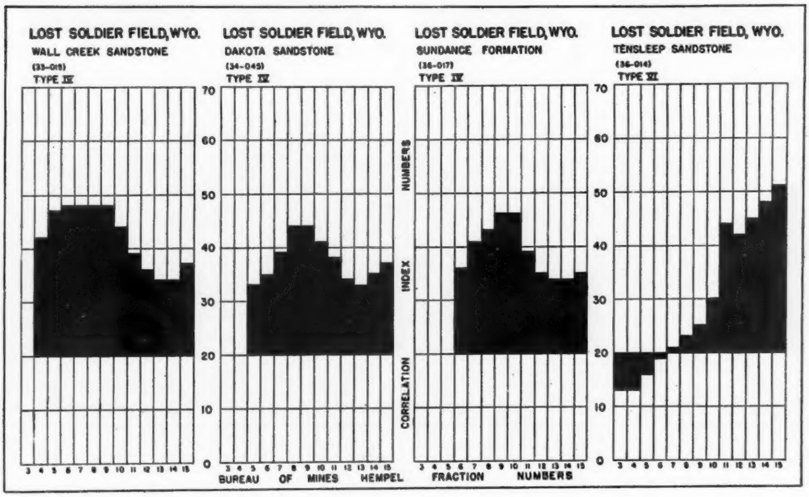

FIG. 9.—Index graphs of representative Lost Soldier oils.

follows: five of nine Wall Creek sands, the Muddy, the Dakota, the Lakota, the Morrison, the Sundance, and the Tensleep. The Mowry could probably produce, but is usually cased off because the deeper sands are larger producers.

The correlation indexes indicate that the Cretaceous and Jurassic oils are Type IV and are similar, whereas the Tensleep oil is Type VI and entirely unlike the others. The Type IV oils are of about the same gravity and the same physical and chemical characteristics, indicating rather strongly the intercommunication of the sands by faults and fractures through which the oils have migrated and mingled. The Tensleep oil apparently has had no opportunity to migrate and mingle with the Type IV oils and has retained its distinct characteristics.

Salt Creek field.—The Salt Creek field produces oil from ten zones, as follows: The Niobrara-Carlile shales, the First, Second, and Third Wall Creek sands of

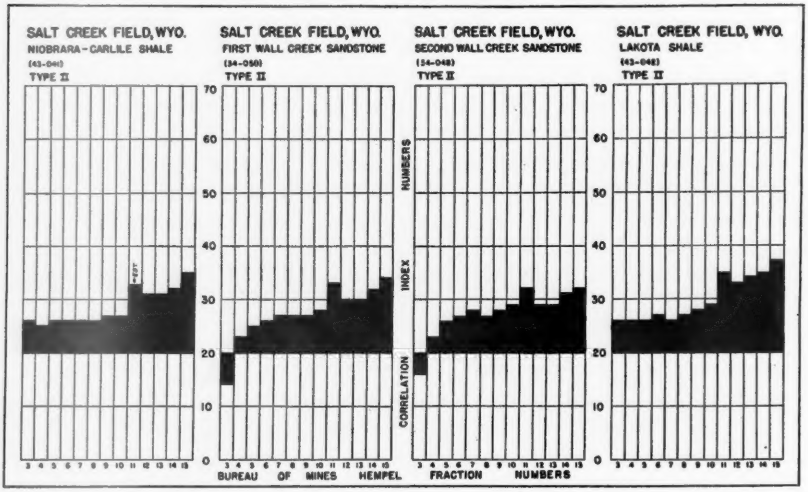

FIG. 10.—Index graphs of representative Salt Creek oils.

the Frontier formation, the Muddy sand, locally called the "Lakota shale," the Lakota sandstone, the Morrison formation, the Second and Third Benches of the Sundance formation, and the Tensleep sandstone. Oil showings were found in the Dakota sandstone and the Madison limestone.

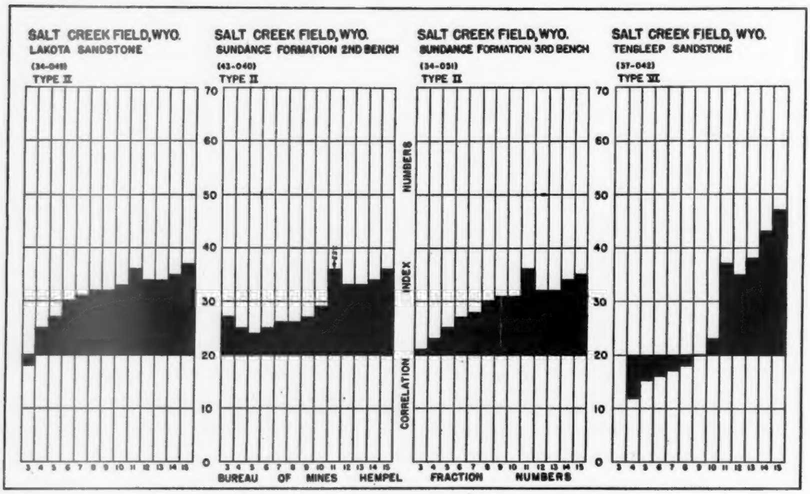

FIG. 11.—Index graphs of representative Salt Creek oils.

The correlation indexes on Figures 10 and 11 indicate that the Cretaceous and Jurassic oils are Type II, resembling each other in many respects, although differing to some extent in gravity, gasoline content, and other minor characteristics. A critical comparison of the eight graphs shows some grouping: the Niobrara-Carlile and "Lakota shale" oils are markedly similar, as are the First and Second Wall Creek oils, and the Lakota and Third Sundance oils. The Niobrara-Carlile and "Lakota shale" oils may have migrated from one or more of the main sand bodies under like conditions, which may account for their similarity; the Wall Creek oils are from the same formation, the Frontier; and the Lakota and Third Sundance yielded flowing wells of generally high initial production. The Tensleep oil, and the showing in the Madison, are the high-sulphur Type VI. Here one might postulate the same or similar source beds for the Cretaceous and Jurassic oils, and a different source for the Tensleep oil. The field is highly faulted in the upper formations, so migration between formations can not be ruled out.

CONCLUSIONS

The writers believe that the oils of the Rocky Mountain region can be grouped by the use of correlation indexes into six types, and that those oils which do not satisfactorily fit these types can be classified under four intermediate types. Four-fifths of the oils discussed are Type II, which prevails in the Cretaceous and Jurassic deposits of Colorado and Wyoming, Type VI, which prevails in the pre-Jurassic deposits of Wyoming, or their intermediate Type II-VI, which prevails in Montana.

APPENDIX

Correlation Indices for Hempel Fractions
(Based on average barometric pressure of 635 mm. of mercury)

Fraction 2

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.650	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6
0.660	5.1	5.6	6.0	6.5	7.0	7.5	7.9	8.4	8.9	9.3
0.670	9.8	10	11	11	12	12	13	13	14	14
0.680	15	15	16	16	17	17	17	18	18	19
0.690	19	20	20	21	21	22	22	23	23	24
0.700	24	25	25	26	26	26	27	27	28	28
0.710	29	29	30	30	31	31	32	32	33	33

Fraction 3

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.680	4.4	4.8	5.3	5.8	6.3	6.7	7.2	7.7	8.1	8.6
0.690	9.1	9.6	10	11	11	12	12	12	13	13
0.700	14	14	15	15	16	16	17	17	18	18
0.710	19	19	20	20	21	21	21	22	22	23
0.720	23	24	24	25	25	26	26	27	27	28
0.730	28	29	29	30	30	30	31	31	32	32
0.740	33	33	34	34	35	35	36	36	37	37
0.750	38	38	39	39	39	40	40	41	41	42

Fraction 4

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.700	4.9	5.4	5.9	6.4	6.8	7.3	7.8	8.2	8.7	9.2
0.710	9.7	10	11	11	12	12	13	13	14	14
0.720	14	15	15	16	16	17	17	18	18	19
0.730	19	20	20	21	21	22	22	23	23	23
0.740	24	24	25	25	26	26	27	27	28	28
0.750	29	29	30	30	31	31	32	32	32	33
0.760	33	34	34	35	35	36	36	37	37	38
0.770	38	39	39	40	40	41	41	41	42	42

Fraction 5

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.720	6.5	7.0	7.5	7.9	8.4	8.9	9.3	9.8	10	11
0.730	11	12	12	13	13	14	14	15	15	16
0.740	16	17	17	17	18	18	19	19	20	20
0.750	21	21	22	22	23	23	24	24	25	25
0.760	26	26	26	27	27	28	28	29	29	30
0.770	30	31	31	32	32	33	33	34	34	35
0.780	35	35	36	36	37	37	38	38	39	39
0.790	40	40	41	41	42	42	43	43	44	44

Fraction 6

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.730	4.3	4.8	5.3	5.8	6.2	6.7	7.2	7.7	8.1	8.6
0.740	9.1	9.6	10	11	11	12	12	12	13	13
0.750	14	14	15	15	16	16	17	17	18	18
0.760	19	19	20	20	21	21	21	22	22	23
0.770	23	24	24	25	25	26	26	27	27	28
0.780	28	29	29	30	30	30	31	31	32	32
0.790	33	33	34	34	35	35	36	36	37	37
0.800	38	38	39	39	39	40	40	41	41	42
0.810	42	43	43	44	44	45	45	46	46	47
0.820	47	48	48	48	49	49	50	50	51	51

Fraction 7

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.750	7.6	8.1	8.6	9.0	9.5	10	11	11	11	12
0.760	12	13	13	14	14	15	15	16	16	17
0.770	17	18	18	19	19	20	20	20	21	21
0.780	22	22	23	23	24	24	25	25	26	26
0.790	27	27	28	28	29	29	29	30	30	31
0.800	31	32	32	33	33	34	34	35	35	36
0.810	36	37	37	38	38	38	39	39	40	40
0.820	41	41	42	42	43	43	44	44	45	45
0.830	46	46	47	47	47	48	48	49	49	50
0.840	50	51	51	52	52	53	53	54	54	55
0.850	55	56	56	56	57	57	58	58	59	59

Fraction 8

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.760	6.6	7.0	7.5	8.0	8.5	8.9	9.4	9.9	10	11
0.770	11	12	12	13	13	14	14	15	15	16
0.780	16	17	17	18	18	18	19	19	20	20
0.790	21	21	22	22	23	23	24	24	25	25
0.800	26	26	27	27	27	28	28	29	29	30
0.810	30	31	31	32	32	33	33	34	34	35
0.820	35	36	36	36	37	37	38	38	39	39
0.830	40	40	41	41	42	42	43	43	44	44
0.840	45	45	45	46	46	47	47	48	48	49
0.850	49	50	50	51	51	52	52	53	53	54
0.860	54	54	55	55	56	56	57	57	58	58
0.870	59	59	60	60	61	61	62	62	63	63
0.880	63	64	64	65	65	66	66	67	67	68

Fraction 9

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.770	6.1	6.6	7.0	7.5	8.0	8.5	8.9	9.4	9.9	10
0.780	11	11	12	12	13	13	14	14	15	15
0.790	16	16	17	17	18	18	18	19	19	20
0.800	20	21	21	22	22	23	23	24	24	25
0.810	25	26	26	27	27	27	28	28	29	29
0.820	30	30	31	31	32	32	33	33	34	34
0.830	35	35	36	36	36	37	37	38	38	39
0.840	39	40	40	41	41	42	42	43	43	44
0.850	44	45	45	45	46	46	47	47	48	48
0.860	49	49	50	50	51	51	52	52	53	53
0.870	54	54	54	55	55	56	56	57	57	58
0.880	58	59	59	60	60	61	61	62	62	63

Fraction 10

0.780	5.9	6.4	6.9	7.4	7.8	8.3	8.8	9.2	9.7	10
0.790	11	11	12	12	13	13	14	14	15	15
0.800	15	16	16	17	17	18	18	19	19	20
0.810	20	21	21	22	22	23	23	24	24	24
0.820	25	25	26	26	27	27	28	28	29	29
0.830	30	30	31	31	32	32	33	33	33	34
0.840	34	35	35	36	36	37	37	38	38	39
0.850	39	40	40	41	41	42	42	42	43	43
0.860	44	44	45	45	46	46	47	47	48	48
0.870	49	49	50	50	51	51	51	52	52	53
0.880	53	54	54	55	55	56	56	57	57	58
0.890	58	59	59	60	60	60	61	61	62	62

Fraction 11

0.800	11	11	12	12	12	13	13	14	14	15
0.810	15	16	16	17	17	18	18	19	19	20
0.820	20	21	21	21	22	22	23	23	24	24
0.830	25	25	26	26	27	27	28	28	29	29
0.840	30	30	30	31	31	32	32	33	33	34
0.850	34	35	35	36	36	37	37	38	38	39
0.860	39	39	40	40	41	41	42	42	43	43
0.870	44	44	45	45	46	46	47	47	48	48
0.880	48	49	49	50	50	51	51	52	52	53
0.890	53	54	54	55	55	56	56	57	57	57
0.900	58	58	59	59	60	60	61	61	62	62
0.910	63	63	64	64	65	65	66	66	66	67
0.920	67	68	68	69	69	70	70	71	71	72

Fraction 12

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.810	11	11	12	12	13	13	14	14	15	15
0.820	16	16	17	17	18	18	19	19	19	20
0.830	20	21	21	22	22	23	23	24	24	25
0.840	25	26	26	27	27	28	28	28	29	29
0.850	30	30	31	31	32	32	33	33	34	34
0.860	35	35	36	36	37	37	37	38	38	39
0.870	39	40	40	41	41	42	42	43	43	44
0.880	44	45	45	46	46	46	47	47	48	48
0.890	49	49	50	50	51	51	52	52	53	53
0.900	54	54	55	55	55	56	56	57	57	58
0.910	58	59	59	60	60	61	61	62	62	63
0.920	63	64	64	64	65	65	66	66	67	67
0.930	68	68	69	69	70	70	71	71	72	72
0.940	73	73	73	74	74	75	75	76	76	77

Fraction 13

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.820	12	13	13	14	14	15	15	16	16	17
0.830	17	18	18	19	19	19	20	20	21	21
0.840	22	22	23	23	24	24	25	25	26	26
0.850	27	27	28	28	28	29	29	30	30	31
0.860	31	32	32	33	33	34	34	35	35	36
0.870	36	37	37	37	38	38	39	39	40	40
0.880	41	41	42	42	43	43	44	44	45	45
0.890	46	46	46	47	47	48	48	49	49	50
0.900	50	51	51	52	52	53	53	54	54	55
0.910	55	55	56	56	57	57	58	58	59	59
0.920	60	60	61	61	62	62	63	63	64	64
0.930	64	65	65	66	66	67	67	68	68	69
0.940	69	70	70	71	71	72	72	73	73	73
0.950	74	74	75	75	76	76	77	77	78	78

Fraction 14

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.830	14	14	15	15	16	16	17	17	18	18
0.840	19	19	20	20	21	21	22	22	22	23
0.850	23	24	24	25	25	26	26	27	27	28
0.860	28	29	29	30	30	31	31	31	32	32
0.870	33	33	34	34	35	35	36	36	37	37
0.880	38	38	39	39	40	40	40	41	41	42
0.890	42	43	43	44	44	45	45	46	46	47
0.900	47	48	48	49	49	49	50	50	51	51
0.910	52	52	53	53	54	54	55	55	56	56
0.920	57	57	58	58	58	59	59	60	60	61
0.930	61	62	62	63	63	64	64	65	65	66
0.940	66	67	67	67	68	68	69	69	70	70
0.950	71	71	72	72	73	73	74	74	75	75
0.960	76	76	76	77	77	78	78	79	79	80
0.970	80	81	81	82	82	83	83	84	84	85

Fraction 15

Specific Gravity	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
0.840	16	16	17	17	18	18	19	19	19	20
0.850	20	21	21	22	22	23	23	24	24	25
0.860	25	26	26	27	27	28	28	28	29	29
0.870	30	30	31	31	32	32	33	33	34	34
0.880	35	35	36	36	37	37	37	38	38	39
0.890	39	40	40	41	41	42	42	43	43	44
0.900	44	45	45	46	46	46	47	47	48	48
0.910	49	49	50	50	51	51	52	52	53	53
0.920	54	54	55	55	55	56	56	57	57	58
0.930	58	59	59	60	60	61	61	62	62	63
0.940	63	64	64	64	65	65	66	66	67	67
0.950	68	68	69	69	70	70	71	71	72	72
0.960	73	73	73	74	74	75	75	76	76	77
0.970	77	78	78	79	79	80	80	81	81	82
0.980	82	82	83	83	84	84	85	85	86	86
0.990	87	87	88	88	89	89	90	90	91	91

OIL FIELDS OF THE ROCKY MOUNTAIN REGION

FIELD	LOCATION		PRODUCTIVE ZONE		TYPE OF OIL	NUMBER OF WELLS					PRODUCTION IN BARRELS			YEAR OF FIRST PROD	DEEPEST DRILLED	
	T.	R.	FORMATION	MEMBER OR LOCAL NAME		PRODUCIBLE 1-1-43 T.	K.	J.	PRE-J	TOTAL DRILLED	1941	1942	ACCUMULATED TOTALS		FORMATION	DEPTH
COLORADO.															as of June 30, 1943	
Berthoud	4 N.	69 W.	Dakota	Upper (Muddy)	II		1			25	3,090	3,017	63,349	1930	Dakota	4,031
Boulder	1-2 N.	70-1 W.	Pierre		II		3			215	4,893	4,200	658,877	1902	Dakota	6,145
De Beque	8 S.	97 W.	Mesaverde				0			28	0	0	non-com.	1902	Mesaverde	3,542
Florence-Canon City	18-9-20S.	69-70 W.	Pierre		II		70			1280	53,546	48,683	13,781,555	1862	Dakota	4,500
Fort Collins	8 N.	68 W.	Dakota	Upper, Middle	II		7			43	45,235	31,992	2,264,039	1924	Lykins	5,206
Greasewood	6 N.	61 W.	Dakota	Upper (Muddy)	II		1			11	7,104	4,518	475,312	1930	Morrison	7,042
Hiawatha (East)	12 N.	100 W.	Wasatch	Hiawatha 1,2,3	I, II-I	8				16	191,572	184,183	520,161	1932	Mesaverde	7,577
Iles	4 N.	92 W.	Mancos		II		3									
"	"	"	Morrison		II			1								
"	"	"	Sundance		II			21		57	555,946	543,745	9,617,594	1925	Nugget	4,166
Mancos Creek	32 N.	18 W.	Mancos		II		0			33	0	0	5,797	1931	Dakota	1,280
Moffat (Hamilton)	4-5 N.	91 W.	Dakota		II		4									
" "	"	"	Sundance		II			7		28	115,529	125,288	5,922,344	1924	Nugget	4,852
North McCallum	9 N.	79 W.	Dakota	Upper	V		1			10	1,626	10,422	87,914	1927	Morrison (drg)	5,129
Powder Wash	12 N.	97 W.	Wasatch	Hiawatha, Stewart	I, II-I	2				8	40,154	36,521	77,929	1937	Laramie	5,878
Price (Gramps)	33 N.	2 E.	Dakota	(and Allen	II		12			27	330,017	325,000(?)	1,514,431(?)	1937	Morrison	1,752
Rangely	1-2 N.	102 W.	Mancos		II		31									
"	"	"	Weber		II-VI				1	295	221,258	307,958	1,278,170	1919	Pennsylvanian(?)	7,173
South McCallum	9 N.	78 W.	Dakota	Upper	II		1			9	0	493	6,148	1938	Morrison	5,258
Tow Creek	6 N.	86 W.	Mancos		II		9			43	49,290	47,289	1,784,936	1925	Gneiss	5,310
Wellington	9-10 N.	68 W.	Dakota	Upper (Muddy)	III		13			48	71,532	80,007	5,001,153	1924	Lykins	5,000
Wilson Creek	2-3 N.	94 W.	Morrison		II			9								
" "	"	"	Sundance		II			1		16	451,818	533,959	1,408,082	1937	Sundance	7,198
MONTANA.																
Bannatyne	25-6 N.	1 E.	Ellis	Emrick				0		46	0	0	55,245	1928	Madison	2,000
Bears Den	36 N.	6 E.	Kootenai	Sunburst	II-VI		2			13	2,964	2,134	33,593	1930	Devonian	3,290
Berthelote	36 N.	2 E.	Kootenai	Sunburst	II-VI		1			8	264	0	9,824	1930	Madison	2,683
Border (U. S. only)	37 N.	4 W.	Kootenai	Vanalta, Cosmos	II-VI		13			36	25,149	26,787	839,795	1930	Madison	2,852
Cat Creek	15 N.	29-30 E.	Colorado	1st Cat Creek	II-VI											
" "	"	"	Kootenai	2nd Cat Creek	II-VI		165			332	167,635	137,649	14,756,986	1920	Cambrian	5,705
Cedar Creek (Montana	4 N.	62 E.	Madison		II-VI				0							
" " only)	to 11 N.	to 57 E.	Bighorn (?)		II-VI				0	245	9,702	0	28,144	1936	Pre-Cambrian	9,680
Conrad-Midway	28 N.	1 W.	Kootenai	Sunburst	II-VI		0			4	0	0	0	1942	Madison (drg)	2,220
Cut Bank	32 N.	4 W.	Kootenai	Moulton, Lander,												
" "	to 37 N.	to 6 W.	"	Sunburst, Cut Bank	II-VI		728			971	5,055,016	5,514,925	31,559,005	1932	Madison	3,260
Devils Basin	11 N.	24 E.	Quadrant (Heath)	Van Dusen	II-VI				3	33	0	0	20,422	1921	Madison	2,505
Dry Creek	7 S.	21 E.	Cloverly	Greybull, Pryor	II-V		6			22	171,700	107,149	1,973,034	1930	Tensleep	6,887
Elk Basin (Mont. only)	9 S.	23 E.	Frontier	Torchlight, Peay			23			36	17,635	16,044	847,539	1916	Chugwater (drg)	5,265
Flat Coulee	37 N.	5 E.	Kootenai	Sunburst	II-VI		2			3	487	80	6,665	1935	Madison	3,015
Frannie (Mont. only)	9 S.	25 E.	Tensleep						2	2	26,796	21,029	53,189	1940	Tensleep	3,561
Kevin-Sunburst	32 N.	1 W.	Kootenai	Burwash, Sunburst	II-VI		104									
" "	to	to	Ellis	Strays	II-VI			42								
" "	36 N.	4 W.	Madison		II-VI				1064	2740	1,735,440	1,953,796	40,883,660	1922	Cambrian	4,690
Lake Basin (Big Lake)	1 N.	21 E.	Cloverly	Greybull	V		2			40	16,703	16,957	412,338	1925	Madison	6,002
Mosser Dome	3 S.	24 E.	Cloverly	Greybull	III		2			21	0	0	5,588	1936	Madison	2,568
Pondera	27 N.	4 W.	Madison		II-VI				156	189	281,748	261,005	6,219,455	1928	Madison	2,354
Soap Creek	6 S.	32 E.	Tensleep (?)		VI				0							
" "	"	"	Amsden		VI				6	14	0	150	127,645	1921	Madison	2,260
Twin Rivers (Reagan)	37 N.	7 W.	Madison		II-VI				1	2	0	2,925	2,925	1942	Madison (drg)	4,084
Whitlash	37 N.	3-4 E.	Colorado	Blackleaf	II-VI		4									
"	"	"	Kootenai	Sunburst	II-VI		1			42	4,018	3,187	73,709	1932	Madison	2,730
UTAH.																
San Juan (Mexican Hat)	42 S.	19 E.	Rico	Goodridge, etc.	II				0	119	0	0	14,000	1910	Granite	3,633
Virgin	41 S.	12 W.	Moenkopi	Rock Canyon	II				21	137	3,635	1,685	183,310	1907	Supai	2,195

27821

Table I-Sheet I

OIL FIELDS OF THE ROCKY MOUNTAIN REGION

FIELD	LOCATION T.	LOCATION R.	PRODUCTIVE ZONE: FORMATION	PRODUCTIVE ZONE: MEMBER OR LOCAL NAME	TYPE OF OIL	NUMBER OF WELLS: PRODUCIBLE 1-1-43: T.	K.	J.	PRE-J	TOTAL DRILLED	PRODUCTION IN BARRELS: 1941	1942	ACCUMULATED TOTALS	YEAR OF FIRST PROD	DEEPEST DRILLED: FORMATION	DEPTH
WYOMING.															as of June 30, 1943	
Alkali Butte	33-4 N.	95 W.	Steele	Shannon			0									
" "	"	"	Thermopolis	Muddy			1			21	0	0	10,617	1928	Chugwater	5,459
Ant Hills	37 N.	63 W.	Graneros	Newcastle	II		0			3	0	0	13,110	1928	Pahasapa	6,825
Aspen	14 N.	118 W.	Bear River		III		2			29	0	0	non-com.	1927	Bear River (?)	5,092
Badger Basin	57 N.	101 W.	Frontier	Torchlight, Peay	II		4			6	57,469	42,446	482,841	1931	Morrison	10,121
Big Hollow (North)	15 N.	75 W.	Thermopolis	Muddy	III		1			17	0	970	3,751	1924	Tensleep	2,583
Big Medicine Bow	21 N.	79 W.	Sundance	First, Second	V			10		22	250,388	243,760	3,747,226	1936	Granite	7,847
Big Muddy	33 N.	76 W.	Steele	Shannon	II		34									
" "	"	"	Niobrara	Strays	II		9									
" "	"	"	Frontier	Wall Creeks	II		119									
" "	"	"	Cloverly	Dakota, Lakota	II		6			406	421,674	401,671	27,815,746	1916	Madison	6,597
Billy Creek	48 N.	82 W.	Frontier	Wall Creek	III		1			15	0	0	non-com.	1935	Bighorn	7,775
Bison Basin	27 N.	95 W.	Frontier		III		1			10	0	0	non-com.	1929	Tensleep	4,923
Black Mountain	43 N.	90-1 W.	Embar		VI				2							
" "	"	"	Tensleep		VI				3	8	22,905	18,421	362,497	1925	Madison	3,892
Bolton Creek	29 N.	81 W.	Sundance		VI			0								
" "	"	"	Embar		VI				0	15	0	0	43,335	1920	Tensleep	2,530
Brenning Basin(Douglas)	32 N.	73 W.	White River		III	5				70	0	0	7,052	1902	Dakota	3,030
Byron	56 N.	97 W.	Sundance					1								
"	"	"	Embar		VI				1							
"	"	"	Tensleep		VI				20	34	1,096,409	1,683,676	6,036,263	1929	Amsden	6,060
Circle Ridge	6 N.	2-3 W.	Embar		VI				4							
" "	"	"	Tensleep		VI				7	13	0	57,789	59,253	1923	Tensleep	803
Cole Creek	35 N.	77 W.	Steele	Shannon	II		20									
" "	"	"	Cloverly	Dakota, Lakota	II		0			25	296,017	374,564	875,894	1938	Chugwater	8,707
Crooks Gap	28 N.	93 W.	Frontier				0			6	0	0	non-com.	1925	Thermopolis	4,725
Crystal Creek	54 N.	93 W.	Tensleep		VI				0	11	0	0	non-com.	1919	Madison	1,805
Dallas	32 N.	99 W.	Chugwater						0							
"	"	"	Embar		VI				27							
"	"	"	Tensleep		VI				4	61	126,342	169,340	2,860,225	1884	Tensleep	2,005
Derby	31 N.	98 W.	Embar		VI				6							
"	"	"	Tensleep		VI				5	23	17,901	14,462	553,029	1922	Amsden	2,435
Dewey	41 N.	60 W.	Minnelusa		VI				1	13	201	100	19,226	1938	Pahasapa	2,890
Dry Piney	28 N.	113-4 W.	Hilliard				0			37	0	0	non-com.	1918	Bear River (?)	8,194
Dutton Creek	18 N.	78 W.	Thermopolis	Muddy	II		3			21	18,709	17,482	303,403	1927	Sundance	5,466
East Lance Creek	36 N.	64 W.	Fall River	Dakota	II		1			19	13,677	13,339	228,288	1919	Pahasapa	6,434
East Mahoney	26 N.	87 W.	Tensleep		II-VI				2	24	63,334	17,602	95,359	1940	Tensleep	4,327
Elk Basin (Wyo. only)	58 N.	99-100 W.	Frontier	Torchlight, Peay	II, II-III		113									
" " " "	"	"	Tensleep		VI				1	171	202,176	171,816	10,522,111	1916	Amsden (?)	4,426
Ferris (East & West)	26 N.	87 W.	Mowry, Thermopolis	Shale, Muddy	II		0									
" " "	"	"	Cloverly	Dakota			0									
" " "	"	"	Sundance					0								
" " "	"	"	Chugwater	Parco					0	43	0	0	281,690	1919	Tensleep	5,057
Fourbear	48 N.	103 W.	Tensleep		VI				1	4	0	0	4,136	1929	Amsden	3,350
Frannie (Wyo. only)	58 N.	98 W.	Tensleep		VI				25							
" " "	"	"	Madison		VI				1	31	1,085,578	1,173,741	6,651,945	1929	Madison	3,271
Garland	56 N.	97-8 W.	Frontier	Peay	II		4									
"	"	"	Tensleep		VI				1							
"	"	"	Madison		VI				18	127	563,785	492,791	7,188,902	1907	Bighorn (?)	4,424
Gooseberry	47 N.	100 W.	Embar		VI											
"	"	"	Tensleep		VI				1	4	0	12,009	12,009	1942	Tensleep	6,076
G. P. Dome	25 N.	86 W.	Niobrara	G. P. sand	II		3			15	1,332	1,331	178,948	1919	Frontier	5,465
Grass Creek	46 N.	98-9 W.	Frontier		II		320									
" "	"	"	Morrison					1								
" "	"	"	Chugwater		VI				1							
" "	"	"	Embar		VI				5							
" "	"	"	Tensleep						10	419	1,156,950	1,525,397	31,279,776	1915	Amsden	4,336
Greybull	52 N.	93 W.	Cloverly	Greybull	V		14			136	2,000	3,223	279,411	1915	Tensleep	2,950
Hamilton Dome	44 N.	98 W.	Chugwater	Curtis	VI				1							
" "	"	"	Embar		VI				32							
" "	"	"	Tensleep		VI				1	38	296,408	429,231	6,165,524	1918	Tensleep	2,886
Hidden Dome	48 N.	90-1 W.	Frontier		IV		15			49	28,953	19,696	335,933	1932	Morrison	2,790

23521

Table I-Sheet II

OIL FIELDS OF THE ROCKY MOUNTAIN REGION

OIL FIELDS OF THE ROCKY MOUNTAIN REGION

FIELD	LOCATION T.	LOCATION R.	PRODUCTIVE ZONE FORMATION	PRODUCTIVE ZONE MEMBER OR LOCAL NAME	TYPE OF OIL	NUMBER OF WELLS PRODUCIBLE 1-1-43 T.	K.	J.	PRE-J	TOTAL DRILLED	PRODUCTION IN BARRELS 1941	1942	ACCUMULATED TOTALS	YEAR OF FIRST PROD	DEEPEST DRILLED FORMATION	DEPTH
WYOMING (Continued).															as of June 30,	1943.
Horse Creek	16-7 N.	68 W.	Thermopolis	Muddy	II		0									
" "	"	"	Cloverly	Lakota	II		1			2	0	4,266	4,266	1942	Chugwater	6,107
Iron Creek	32 N.	82 W.	Cloverly	Dakota	II		4			10	4,571	3,514	43,961	1926	Sundance	1,633
Kirby Creek	43 N.	92 W.	Frontier		II, II-III		7			36	9,496	7,761	61,186	1919	Cloverly	1,668
La Barge	26-7 N.	113 W.	Eocene (?)	1, 2, 3 oil sd	III, II-I	153				232	735,151	733,885	7,987,231	1924	Hilliard	4,886
Lake Creek	43 N.	91 W.	Embar		VI				1	5	0	0	13,343	1925	Tensleep	4,400
Lance Creek	35-6 N.	65 W.	Fall River	Dakota	II		7									
" "	"	"	Sundance	Upper, Basal	II			73								
" "	"	"	Minnelusa	Converse, Leo	II				136	315	8,921,981	7,970,756	49,013,437	1918	Deadwood	6,256
Lander (Hudson)	2 S.	1-2 E.	Embar		VI				30							
" "	& 33 N.	99 W.	Tensleep		VI				5	45	98,751	99,134	2,330,674	1915	Tensleep	2,148
Lost Soldier	26 N.	90 W.	Frontier	Wall Creeks	IV		25									
" "	"	"	Thermopolis	Muddy	IV		0									
" "	"	"	Cloverly	Dakota, Lakota	IV		14									
" "	"	"	Morrison		IV			1								
" "	"	"	Sundance		IV			21								
" "	"	"	Tensleep		VI				11	155	2,333,105	2,360,264	25,703,541	1917	Tensleep	6,475
Mahoney (West)	26 N.	88 W.	Frontier				0									
" "	"	"	Tensleep		VI				9	29	470,984	381,786	1,145,354	1922	Amsden	4,694
Maverick Springs	6 N.	2 W.	Embar		VI				32	45	526,852	753,566	1,361,458	1918	Tensleep	2,094
Midway	35 N.	79 W.	Frontier	Second Wall Creek	II		2									
"	"	"	Thermopolis	Muddy			1			8	0	0	129,603	1932	Chugwater	6,689
Moorcroft	52 N.	67 W.	Graneros	Newcastle			4			16	0	0	800	1920	Deadwood	3,511
Mule Creek (East)	39 N.	60-1 W.	Lakota		II		40									
" " "	"	"	Minnelusa	Leo	VI				1	54	134,208	131,278	1,764,004	1919	Minnelusa	3,172
Newcastle	45 N.	61 W.	Graneros	Newcastle	III		1			3	0	250	250	1942	Graneros	620
North Baxter Basin	19-20 N.	103-4 W.	Morrison (?)		II			0		15	242	304	554	1936	Tensleep	6,455
North Casper Creek	36-7 N.	82 W.	Tensleep		VI				2	16	0	0	8,964	1930	Tensleep	3,400
Northern Hiawatha	12 N.	99 W.	Wasatch	Hiawatha	I	0				1	0	0	0	1942	Wasatch	3,470
North La Barge	27 N.	113 W.	Eocene (?)		II-I	4										
" " "	"	"	Hilliard		II-I		1			14	6,456	7,440	44,029	1931	Cretaceous (drg)	7,950
North Oregon Basin	51-2 N.	100 W.	Embar		VI				23							
" " "	"	"	Tensleep		VI				10							
" " "	"	"	Madison						0	52	1,343,633	1,779,070	9,466,070	1927	Madison	4,502
North Sunshine	47 N.	101 W.	Tensleep		VI				1	3	0	0	3,016	1928	Amsden	3,780
Notches	37 N.	85 W.	Tensleep	(Newcastle	VI				4	13	0	44,770	213,320	1923	Tensleep	2,918
Osage	46-7 N.	63-4 W.	Graneros	Belle Fourche,	II		331			988	215,160	197,660	5,174,044	1920	Minnelusa	2,592
Pedro	45-6 N.	62-3 W.	Graneros	Belle Fourche	II		20			44	Included	under	Osage	1924	Niobrara (?)	840
Pilot Butte	3 N.	1 W.	Cody		II		19									
" "	"	"	Embar		VI				1							
" "	"	"	Tensleep		VI				3	107	10,240	187,165	773,046	1916	Amsden	6,775
Pine Mountain	34-5 N.	84 W.	Embar		VI				0	18	0	0	6,354	1914	Deadwood	3,127
Pitchfork	48 N.	102 W.	Embar-Tensleep		VI				1	3	0	0	shut-in	1930	Amsden	3,903
Plunkett	1 S.	1 E.	Mowry		II		10			32	1,717	897	17,020	1921	Morrison	1,916
Poison Spider	33 N.	82-3 W.	Sundance	Lower	VI			20		43	70,216	63,450	1,042,733	1922	Granite	4,119
Powder River	36 N.	85 W.	Frontier	Wall Creek			0			20	0	0	0	1920	Sundance	3,460
Quealy	17 N.	76-7 W.	Thermopolis	Muddy	II		0									
"	"	"	Cloverly	Dakota, Lakota	II		17									
"	"	"	Sundance					0		22	161,882	165,999	1,348,365	1936	Chugwater	4,010
Red Springs	43 N.	93 W.	Madison		VI				1	2	270	2,294	3,340	1939	Madison	1,095
Rex Lake	16 N.	77 W.	Thermopolis	Muddy			2									
" "	"	"	Cloverly	Dakota	II		1			13	20,062	24,064	253,024	1924	Chugwater	4,436
Rock Creek	19-20 N.	78 W.	Thermopolis	Muddy	II		2									
" "	"	"	Cloverly	Dakota, Lakota	II		56									
" "	"	"	Sundance		II			10		110	950,102	932,678	21,735,934	1918	Casper (Tensleep)	5,671
Rocky Ford	52 N.	62 W.	Minnelusa		VI				0	4	0	0	non-com.	1909	Pahasapa	1,323
Sage Creek	1 N.	1 W.	Chugwater		VI				2	12	0	0	(est) 2,000	1934	Madison	1,958
Salt Creek	39-40 N.	78-9 W.	Niobrara-Carlile	Shale	II		50									
" "	"	"	Frontier	1,2,&3 Wall Creek	II		1683									
" "	"	"	Thermopolis	"Lakota" shale	II		15									
" "	"	"	Cloverly	Lakota sand	II		29									
" "	"	"	Morrison		II			1								
" "	"	"	Sundance	2nd & 3rd benches	II			34								
" "	"	"	Tensleep		VI				9	2383	5,087,466	4,955,986	303,150,911	1911	Granite	5,420

23321

Table I-Sheet III

OIL FIELDS OF THE ROCKY MOUNTAIN REGION

FIELD	LOCATION T.	LOCATION R.	PRODUCTIVE ZONE FORMATION	PRODUCTIVE ZONE MEMBER OR LOCAL NAME	TYPE OF OIL	NUMBER OF WELLS PRODUCIBLE 1-1-43 T.	K.	J.	PRE-J	TOTAL DRILLED	PRODUCTION IN BARRELS 1941	1942	ACCUMULATED TOTALS	YEAR OF FIRST PROD	DEEPEST DRILLED FORMATION	DEPTH
WYOMING (Continued).															as of June 30, 1943	
Shannon	40-1 N.	78-9 W.	Steele	Shannon	III		38			45	0	0	55,461	1894	Frontier	3,245
Shawnee	32 N.	69 W.	White River		III	1				47	0	0	shut-in	1937	Granite	2,940
Sheep Creek	28 N.	92 W.	Embar		VI				2	6	0	4,588	6,064	1936	Tensleep	3,290
Shoshone	53 N.	101 W.	Frontier				1									
"	"	"	Thermopolis	Muddy			0									
"	"	"	Embar		VI				1							
"	"	"	Tensleep						1	15	14,729	27,301	103,997	1927	Amsden	4,795
Simpson Ridge	21 N.	80 W.	Mesaverde	Quealy	III		5			22	6,754	4,992	202,859	1925	Frontier (?)	6,931
South Casper Creek	33-4 N.	83 W.	Tensleep		VI				22	39	177,884	177,962	3,056,256	1923	Madison	3,175
South Oregon Basin	50-1 N.	100 W.	Embar		VI				44							
" " "	"	"	Tensleep		VI				8							
" " "	"	"	Madison		VI				0	95	1,377,660	2,606,048	10,875,019	1928	Bighorn (?)	4,663
South Spring Creek	49 N.	102 W.	Embar-Tensleep-Amsden		VI				1	5	1,097	0	39,622	1937	Amsden	4,254
South Sunshine	46 N.	101 W.	Embar		VI				1	2	0	0	7,715	1927	Tensleep	2,845
Spindletop	29-30 N.	81 W.	Sundance		VI			4		13	0	2,941	29,000	1937	Amsden	2,807
Spring Valley	15 N.	118 W.	Frontier													
" "	"	"	Aspen		II											
" "	"	"	Bear River		II		22			95	3,455	3,260	204,900	1902	Bear River	?
Steamboat Butte	3-4 N.	1 W.	Cloverly	Dakota, Lakota	II		0									
" "	"	"	Sundance		VI			0		1	0	0	0	1943	Sundance (drg)	5,137
Sulphur Creek	13 N.	119 W.	Bear River		III		0			3	0	200	200	1942	?	1,015
Teapot(outside reserve)	38 N.	78 W.	Steele	Shannon	II		0									
" " "	"	"	Niobrara	Shale	II		3			20	6,411	5,588	124,671	1925	Frontier	3,340
Teapot(naval reserve)	38-9 N.	78 W.	Steele	Shannon			1									
" " "	"	"	Niobrara, Carlile	Shale			12									
" " "	"	"	Frontier	2nd & 3rd W. C.			46			86	0	0	3,543,282	1922	Frontier	3,340
Thornton	48-9 N.	66 W.	Carlile	"Wall Creek"			0			20	0	0	463	1919	Graneros	1,050
Torchlight	51 N.	92-3 W.	Mowry	Kimball, Ooth Louie	II		10			130	0	0	199,284	1915	Madison	4,165
Wakeman Flats	49 N.	66 W.	Carlile	"Wall Creek"	II		2			20	0	0	non-com.	1919	Fall River	2,159
Warm Springs	43 N.	93-4 W.	Embar		VI				39	66	24,760	18,636	477,440	1917	Amsden	1,945
Waugh	44 N.	96-7 W.	Embar		VI				0	9	0	0	192,611	1935	Tensleep	4,242
Wertz	26 N.	89-90 W.	Mowry				0									
"	"	"	Tensleep		VI				21	38	1,889,959	2,286,703	6,463,789	1921	Amsden	6,700
West Mule Creek	39-40 N.	61 W.	Graneros	Newcastle			1									
" " "	"	"	Fall River, Lakota	Dakota, Lakota	II		20									
" " "	"	"	Minnelusa	Bell	VI				2	48	5,357	4,482	99,996	1931	Pahasapa	3,047
				RECAPITULATION:												
				COLORADO		10	156	39	1	2192	2,142,610	2,287,275	44,467,791			
				MONTANA		0	1053	42	1232	4799	7,515,257	8,063,817	97,908,761			
				UTAH		0	0	0	21	256	3,635	1,685	197,310			
				WYOMING		163	3174	176	604	7641	30,332,819	32,855,795	564,901,961			
				GRAND TOTAL		173	4383	257	1858	14,888	39,994,321	43,208,572	707,475,823			

Note: A well producing from two formations is counted under the lower formation.

Note: Under "Number of Wells"
T - Tertiary
K - Cretaceous
J - Jurassic
Pre-J - Pre-Jurassic

23521

Table I-Sheet IV

CRUDE OILS OF THE ROCKY MOUNTAIN REGION

GEOLOGIC SYSTEM	STATE	FIELD	PRODUCTIVE ZONE	TYPE OF OIL	CORRELATION INDEX NUMBERS 3	4	5	6	7	8	9	10	11	12	13	14	15	GRAVITY °A.P.I.	SULFUR PERCENT	S.U.V. AT 100°F SECS.	CARBON RESIDUE PERCENT	TOTAL GASOLINE PERCENT	BASE OF CRUDE	LABORATORY NUMBER
Tertiary	Colorado	Hiawatha (East)	Hiawatha, 1st oil sd	II-I	19	23	25	25	25	25	27	27	30	27	29	28	28	44.1	-.10	35	0.7	43.5	P	41-03
"	"	" "	Hiawatha, 2nd oil sd	I	40	38	41	43	44	42	40	36	34	30	29	29	28	36.2	-.10	40	0.8	27.0	IP	Av. 5
"	"	" "	Hiawatha, 3rd oil sd	II-I	21	26	27	26	24	23	23	24	29	27	28	29	30	47.6	-.10	32	0.5	51.9	P	Av. 2
"	"	Powder Wash	Hiawatha (Stewart)	I	43	40	38	36	34	33	34	33	36	32	32	30	30	37.6	-.10	36	0.6	34.8	IP	42-023
"	"	" "	Hiawatha (Allen)	II-I	25	26	30	30	28	26	26	27	34	31	30	29	30	37.4	-.10	39	0.9	25.5	P	37-057
"	Wyoming	Brenning Basin	White River	III	15	20	22	23	25	27	32	35	49	47	49	51	54	34.4	0.44	43	2.3	31.8	I	37-068
"	"	La Barge (south)	Eocene (?), 1 oil sd	III	--	--	--	49	51	54	59	62	67	69	71	72	71	20.3	-.10	112	1.9	1.0	N	33-027
"	"	" (center)	Eocene (?), 2 oil sd	III	24	28	29	34	38	42	46	48	55	51	50	48	48	32.8	-.10	40	1.7	22.8	NI	43-022
"	"	" (north)	Eocene (?), 1 oil sd	III	--	--	--	28	33	41	47	52	62	59	60	59	57	26.7	0.20	58	0.9	11.1	NI	Av. 2
"	"	" "	Eocene (?), 3 oil sd	II-I	21	31	32	32	29	28	30	32	32	29	28	26	25	45.8	0.20	33	0.3	41.2	I	33-08
"	"	Northern Hiawatha	Wasatch (Hiawatha)	I	42	41	45	47	48	48	50	47	42	39	37	35	33	37.0	-.10	45	1.1	15.7	IP	43-026
"	"	North La Barge	Eocene (?)	II-I	21	26	28	27	26	25	26	27	32	29	27	26	25	44.1	-.10	35	0.3	41.5	P	42-052
"	"	Shawnee	White River	III	--	--	--	33	34	37	41	44	53	53	55	57	58	25.2	-.10	106	0.9	4.5	NI	38-01
Cretaceous	Colorado	Berthoud	Upper Dakota	II	25	26	26	26	26	26	27	29	35	34	35	37	39	39.6	-.10	38	0.9	36.8	I	43-020
"	"	Boulder	Pierre	II	23	24	25	24	23	24	24	24	31	28	29	30	31	42.6	-.10	37	0.4	36.3	P	43-019
"	"	De Beque	Mesaverde		No Analysis																			
"	"	Florence	Pierre	II	--	14	19	15	15	16	18	19	29	27	28	32	36	30.8	-.10	83	2.6	8.3	PI	36-024
"	"	Fort Collins	Upper Dakota	II	21	20	21	22	24	25	27	28	36	33	34	36	38	35.0	-.10	45	2.1	23.9	I	37-040
"	"	" "	Middle Dakota	II	--	28	23	20	19	20	22	24	--	31	33	36	38	31.9	-.10	67	2.8	14.6	PI	41-08
"	"	Greasewood	Upper Dakota	II	19	22	24	24	23	23	24	25	33	31	30	31	33	41.9	-.10	39	0.9	37.6	PI	37-039
"	"	Iles	Mancos	II	32	29	26	27	28	28	29	30	37	35	37	39	41	33.0	-.10	52	1.9	20.1	I	37-028
"	"	Mancos Creek	Mancos	II	20	27	27	27	29	29	28	26	28	27	31	33	37	34.2	0.18	60	1.2	19.3	PI	32-027
"	"	Moffat	Dakota	II	19	19	20	21	22	24	25	27	35	34	33	36	37	40.4	-.10	38	0.9	35.2	PI	37-036
"	"	North McCallum	Upper Dakota	V	23	19	19	19	19	18	19	19	--	--	--	--	--	52.5	-.10	-32	Tr.	62.5	P	35-011
"	"	Price	Dakota	II	--	--	25	21	21	20	21	22	29	28	30	32	35	30.0	-.10	91	2.5	7.0	PI	38-03
"	"	Rangely	Mancos	II	22	22	21	21	21	21	22	22	30	28	30	32	35	41.1	-.10	38	0.5	32.6	PI	Av. 3
"	"	South McCallum	Upper Dakota	II	--	20	25	24	23	24	25	26	33	31	33	35	36	41.3	-.10	34	0.2	28.0	PI	36-026
"	"	Tow Creek	Mancos	II	21	23	24	25	26	28	28	28	36	34	35	37	40	37.4	-.10	44	1.2	30.2	I	37-047
"	"	Wellington	Upper Dakota	III	21	23	25	27	29	32	33	35	43	43	46	49	51	33.2	-.10	46	2.6	28.7	I	37-038
"	Montana	Bears Den	Sunburst	II-VI	17	18	21	23	24	25	27	29	40	38	39	43	46	38.0	0.77	44	1.9	35.4	I	38-016
"	"	Bertholote	Sunburst	II-VI	30	32	34	35	35	35	34	34	40	37	41	44	46	32.5	0.51	55	2.4	24.5	I	43-047
"	"	Border-Red Coulee	Vanalta-Cosmos	II-VI	30	29	26	29	32	35	38	42	49	48	50	53	53	29.1	1.07	56	3.0	19.7	I	40-024
"	"	Cat Creek	First Cat Creek	II-VI	13	16	20	22	25	27	27	27	32	32	37	--	--	50.4	0.22	-32	0.6	68.3	PI	33-017
"	"	" "	Second Cat Creek	II-VI	14	17	20	22	24	26	27	28	34	34	38	42	--	47.8	0.48	32	0.7	58.2	I	33-012
"	"	Conrad-Midway	Sunburst	II-VI	12	13	15	18	20	22	24	28	39	39	41	44	47	42.6	1.02	35	1.2	40.6	I	43-015
"	"	Cut Bank	Moulton	II-VI	28	24	26	27	27	27	27	30	40	38	41	44	46	37.0	0.81	37	1.9	34.4	I	39-015
"	"	" "	Lander	II-VI	13	17	21	23	25	26	27	31	41	40	42	45	47	36.2	1.02	43	3.0	32.3	I	36-031
"	"	" "	Sunburst	II-VI	14	20	25	27	28	28	30	33	42	40	43	46	47	38.2	1.03	44	1.8	34.0	I	34-029
"	"	" "	Cut Bank	II-VI	12	15	20	23	24	25	26	29	41	38	40	43	45	39.4	0.40	40	1.9	33.9	I	36-029
"	"	Dry Creek	Greybull	II-V	20	24	23	21	19	18	19	19	25	21	20	22	24	51.3	-.10	-32	0.2	52.3	P	33-025
"	"	" "	Pryor	II-V	18	22	20	18	17	17	18	19	24	20	20	22	24	50.9	-.10	33	0.2	46.8	P	33-024
"	"	Elk Basin	Torchlight, Peay		See Wyoming																			
"	"	Flat Coulee	Sunburst	II-VI	--	40	35	33	31	32	33	34	42	41	44	46	46	32.3	0.99	54	2.4	15.0	I	35-013
"	"	Kevin-Sunburst	Colorado (Burwash)	II-VI	15	21	26	28	28	29	30	33	40	39	44	45	52	42.8	1.43	33	1.0	47.7	I	34-07
"	"	" "	Sunburst	II-VI	14	15	18	22	24	25	27	30	42	40	43	45	47	37.2	0.88	39	1.6	31.1	I	37-01
"	"	Lake Basin	Greybull	V	24	27	25	22	20	21	22	22	21	17	17	17	20	43.6	-.10	37	0.4	31.6	P	33-03
"	"	Mosser Dome	Greybull	III	--	--	--	--	--	42	42	41	46	45	47	50	53	21.6	1.58	264	4.4	0	I	37-061
"	"	Whitlash	Blackleaf	II-VI	15	23	27	30	30	30	31	34	40	39	43	47	48	38.4	1.01	36	1.4	37.5	I	34-03
"	"	"	Sunburst	II-VI	19	20	22	24	26	27	29	32	38	37	40	44	46	35.4	0.83	43	3.6	28.7	I	33-09
"	Wyoming	Alkali Butte	Shannon		No Analysis																			
"	"	" "	Muddy		Incomplete Analysis													34.1	-.10	60	-	12.0	I	28-139
"	"	Ant Hills	Newcastle	II	--	--	--	--	20	22	24	24	25	22	23	24	26	28.7	0.14	-	2.8	2.4	P	*37-14
"	"	Aspen	Bear River	III	--	--	--	--	38	45	48	50	52	52	53	53	52	22.1	0.25	760	7.1	6.0	NI	*30-10
"	"	Badger Basin	Frontier	II	19	23	25	25	26	27	28	30	37	35	34	35	36	48.5	-.10	32	0.3	48.6	I	37-064
"	"	Big Hollow	Muddy	III	--	--	--	--	32	35	39	42	--	--	55	58	60	18.6	-.10	930	7.1	3.1	I	38-017
"	"	Big Muddy	Shannon	II	27	26	26	27	28	29	30	32	40	38	39	41	43	33.6	0.13	50	2.2	25.2	I	36-020
"	"	" "	Niobrara	II	--	28	27	29	29	31	32	33	--	37	37	39	40	33.2	-.10	62	1.7	23.0	I	43-050
"	"	" "	Wall Creek	II	23	25	25	27	27	28	30	30	--	34	35	36	38	34.6	0.13	50	1.9	25.5	I	43-04
"	"	" "	Dakota	II	17	17	18	20	20	21	23	25	--	33	33	34	37	36.4	-.10	49	2.1	25.9	PI	42-026
"	"	" "	Lakota	II	28	27	24	24	24	26	28	29	--	33	34	36	38	31.7	0.12	59	3.9	21.0	I	42-024
"	"	Billy Creek	Wall Creek	III	--	--	--	--	48	45	49	50	57	55	56	58	60	19.5	0.31	194	5.6	2.6	NI	39-05
"	"	Bison Basin	Frontier	III	--	--	--	--	40	42	46	51	66	66	70	73	73	16.8	0.38	445	5.9	1.5	N	36-03
"	"	Cole Creek	Shannon	II	--	23	21	20	20	20	22	24	32	30	31	33	36	35.4	0.12	49	1.7	21.8	PI	40-047
"	"	" "	Dakota	II	17	18	18	20	21	24	25	26	34	33	34	35	37	37.2	-.10	44	2.2	26.8	PI	39-033
"	"	" "	Lakota	II	--	20	20	21	22	23	25	26	34	32	32	34	36	32.7	-.10	55	4.5	21.4	PI	38-024

23521

Table II, Sheet I

CRUDE OILS OF THE ROCKY MOUNTAIN REGION

GEOLOGIC SYSTEM	STATE	FIELD	PRODUCTIVE ZONE	TYPE OF OIL	CORRELATION INDEX NUMBERS 3	4	5	6	7	8	9	10	11	12	13	14	15	GRAVITY °A.P.I.	SULFUR PERCENT	S.U.V. AT 100°F SECS.	CARBON RESIDUE PERCENT	TOTAL GASOLINE PERCENT	BASE OF CRUDE	LABORATORY NUMBER
Cretaceous	Wyoming	Crooks Gap	Frontier		No Analysis																			
"	"	Dry Piney	Hilliard		Incomplete Analysis													40.2	0.13	-	-	44.3	-	*
"	"	Dutton Creek	Muddy	II	25	25	27	30	32	33	34	34	37	34	37	40	44	33.4	0.26	52	3.7	27.6	I	*37-125
"	"	East Lance Creek	Dakota	II	20	20	22	21	20	19	21	22	30	27	27	27	28	45.2	-.10	36	0.4	39.5	P	41-010
"	"	Elk Basin	Torchlight	II	20	23	24	25	25	25	27	30	38	34	34	34	37	45.8	-.10	34	0.5	47.9	I	40-048
"	"	" " (south)	Torchlight	II-III	25	30	31	33	34	36	39	41	45	43	46	49	52	37.6	1.07	36	3.0	45.8	I	33-029
"	"	" "	Peay	II	21	23	25	25	26	27	28	29	38	35	37	39	41	45.8	-.10	33	0.6	47.6	I	40-049
"	"	" " (south)	Peay	II-III	29	29	29	29	29	30	33	36	44	43	44	47	50	36.6	1.07	36	2.9	42.9	I	40-08
"	"	Ferris	Mowry & Thermopolis	II	24	24	26	27	29	30	30	29	29	27	28	30	33	36.4	0.23	48	0.8	31.2	I	*294
"	"	"	Dakota		Incomplete Analysis													36.6	0.19	-	-	31.1	-	*
"	"	Garland	Peay	II	24	29	34	36	36	35	36	36	40	38	37	38	38	40.6	-.10	36	0.2	43.4	I	37-011
"	"	G. P. Dome	G. P. sand	II	22	20	20	21	21	23	24	24	33	30	31	33	36	36.4	0.20	46	1.2	24.7	PI	40-033
"	"	Grass Creek	Frontier	II	19	23	25	26	25	25	27	27	36	34	33	34	37	45.2	-.10	34	0.5	45.3	PI	37-016
"	"	Greybull	Greybull	V	18	20	19	18	16	16	17	17	23	20	19	20	20	48.5	-.10	34	0.2	40.4	P	43-036
"	"	Hidden Dome	Frontier	IV	21	32	37	41	44	45	46	43	38	34	31	28	32	43.0	0.21	-32	Tr.	45.5	IP	33-01
"	"	Horse Creek	Muddy	II	28	27	26	25	27	28	29	30	37	35	37	39	41	32.8	0.31	54	1.9	22.9	I	43-043
"	"	" "	Lakota	II	--	--	26	24	25	26	28	28	35	32	34	36	39	30.0	-.10	130	2.4	13.1	I	43-031
"	"	Iron Creek	Dakota	II	--	--	34	32	33	32	34	34	40	38	38	40	41	29.5	-.10	89	2.1	11.9	I	40-03
"	"	Kirby Creek	Frontier	II	20	20	21	24	25	27	29	31	37	35	35	36	37	38.4	-.10	38	0.7	30.7	I	40-050
"	"	" "	Frontier	II-III	--	--	--	--	--	34	36	38	43	41	42	44	45	27.1	-.10	118	1.7	4.5	I	39-027
"	"	Lance Creek	Dakota	II	18	20	22	23	22	21	21	22	28	26	25	25	26	45.4	-.10	35	0.2	40.0	P	37-07
"	"	Lost Soldier	Wall Creek	IV	--	42	47	48	48	48	48	44	39	36	34	34	37	31.0	0.41	49	1.9	14.0	I	33-015
"	"	" "	Muddy	IV	--	--	34	35	40	43	43	41	38	34	33	36	38	30.2	0.22	79	1.7	9.2	I	36-019
"	"	" "	Dakota	IV	--	--	33	35	39	44	44	41	38	34	33	35	37	30.0	0.24	79	1.8	9.2	I	34-045
"	"	" "	Lakota	IV	--	--	34	38	41	44	44	42	38	34	32	33	36	31.1	0.36	71	1.7	10.6	I	33-016
"	"	Mahoney (West)	Frontier		No Analysis																			
"	"	Midway	Second Wall Creek	II	--	29	30	30	31	32	32	34	34	30	32	34	38	28.4	0.37	209	2.9	15.2	I	32-022
"	"	"	Muddy		Incomplete Analysis													31.4	-.10	76	-	19.3	I	31-035
"	"	Moorcroft	Newcastle		Incomplete Analysis													21.9	-	-	-	6.4	-	*
"	"	Mule Creek (East)	Lakota	II	--	23	22	21	23	26	28	28	34	32	33	35	38	31.7	-.10	70	1.9	11.5	I	34-052
"	"	Newcastle	Newcastle	III	--	--	--	--	--	--	--	51	51	54	55	55	56	22.1	0.10	435	2.3	0	NI	42-016
"	"	North La Barge	Hilliard	II-I	24	31	33	32	29	31	34	34	37	33	31	28	26	40.2	-.10	35	0.1	32.8	IP	42-055
"	"	Osage	Belle Fourche	II	25	25	26	27	26	27	30	30	--	33	34	36	39	38.0	-.10	41	1.2	32.8	I	43-035
"	"	"	Newcastle	II	23	28	29	31	31	32	33	33	37	34	36	37	39	39.6	-.10	38	1.2	35.7	I	33-030
"	"	Pedro	Belle Fourche	II	--	25	24	23	25	26	27	29	35	33	37	40	43	29.5	0.22	95	2.3	9.8	I	34-010
"	"	Pilot Butte	Steele	II	--	26	24	23	23	24	24	25	32	30	31	33	36	37.7	-.10	43	1.3	28.8	PI	37-063
"	"	Plunkett	Mowry	II	19	23	25	27	29	30	31	32	36	34	35	37	38	40.9	-.10	39	0.3	34.6	I	39-04
"	"	Powder River	Wall Creek		No Analysis																			
"	"	Quealy	Muddy	II	21	19	20	21	22	24	26	27	35	32	33	36	39	34.4	-.10	53	1.8	24.5	PI	35-017
"	"	"	Dakota-Lakota	II	18	15	18	19	19	20	23	25	35	33	34	36	38	34.0	0.27	58	2.9	21.4	PI	36-011
"	"	Rex Lake	Muddy		No Analysis																			
"	"	" "	Dakota	II	18	22	23	24	24	27	29	30	36	34	34	37	39	34.8	-.10	52	2.6	26.2	I	42-013
"	"	Rock Creek	Muddy	II	22	25	26	26	26	27	29	30	--	35	36	37	39	35.8	-.10	46	2.2	29.7	I	43-055
"	"	" "	Dakota	II	20	23	24	26	27	27	28	30	38	35	34	36	38	37.2	0.17	45	2.2	30.0	I	37-04
"	"	" "	Lakota	II	20	23	24	23	23	26	29	29	--	35	36	38	39	37.0	-.10	43	2.9	30.3	I	43-056
"	"	Salt Creek	Niobrara-Carlile	II	26	25	26	26	26	26	27	27	--	31	31	32	35	36.2	-.10	47	1.5	26.6	PI	43-041
"	"	" "	First Wall Creek	II	14	23	25	26	27	27	27	28	33	30	30	32	34	37.4	-.10	43	1.6	28.5	I	34-050
"	"	" "	Second Wall Creek	II	16	23	26	27	28	27	28	29	32	29	29	31	32	37.6	-.10	45	1.7	32.1	I	34-048
"	"	" "	Third Wall Creek	II	14	21	24	25	25	26	27	28	34	32	32	34	36	37.4	-.10	42	1.6	28.6	I	34-053
"	"	" "	"Lakota" shale	II	26	26	26	27	26	27	28	29	35	33	34	35	37	36.4	-.10	46	1.6	28.1	I	43-042
"	"	" "	Lakota sand	II	18	25	27	30	31	32	32	33	36	34	34	35	37	36.9	0.12	41	2.8	28.1	I	34-049
"	"	Shannon	Shannon	III	--	--	--	50	54	54	52	49	50	48	48	49	48	24.2	0.20	-	2.7	0	NI	*556
"	"	Shoshone	Frontier		No Analysis																			
"	"	"	Muddy		No Analysis																			
"	"	Simpson Ridge	Quealy	III	--	--	--	---	--	42	45	48	56	55	56	58	60	22.1	-.10	184	2.5	0	NI	38-07
"	"	Spring Valley	Frontier		No Analysis																			
"	"	" "	Aspen	II	22	22	22	22	21	22	24	24	31	30	31	33	37	40.4	-.10	39	0.5	32.0	PI	37-071
"	"	" "	Bear River	II	21	22	23	23	24	25	25	25	32	29	29	30	33	40.9	-.10	38	0.7	32.9	P	37-010
"	"	x Sulphur Creek	Bear River	III	--	--	--	--	--	51	52	54	--	58	61	64	66	17.1	-.10	1630	4.4	0	N	43-048
"	"	Teapot (outside)	Shannon	II	18	22	26	30	35	39	41	40	38	35	34	36	38	32.3	-.10	54	1.1	16.2	I	34-037
"	"	" "	Niobrara	II	20	24	26	28	28	28	29	29	35	32	33	36	38	43.0	-.10	38	0.6	39.1	I	33-036
"	"	Teapot (reserve)	Shannon		No Analysis																			
"	"	" "	Niobrara-Carlile		No Analysis																			
"	"	" "	2 & 3 Wall Creek		No Analysis																			
"	"	Thornton	Carlile		No Analysis																			

23521

Table II, Sheet II

CRUDE OILS OF THE ROCKY MOUNTAIN REGION

GEOLOGIC SYSTEM	STATE	FIELD	PRODUCTIVE ZONE	TYPE OF OIL	CORRELATION INDEX NUMBERS 3	4	5	6	7	8	9	10	11	12	13	14	15	GRAVITY °A.P.I.	SULFUR PERCENT	S.U.V AT 100°F SECS.	CARBON RESIDUE PERCENT	TOTAL GASOLINE PERCENT	BASE OF CRUDE	LABORATORY NUMBER
Cretaceous	Wyoming	Torchlight	Kimball-Coth Louie	II	34	29	26	25	25	26	26	26	32	30	30	31	33	40.4	-.10	37	0.2	32.1	PI	40-038
"	"	Wakeman Flats	Carlile	II	17	21	22	24	25	27	28	29	35	33	33	35	37	38.6	-.10	52	1.1	31.6	I	38-023
"	"	West Mule Creek	Newcastle		No Analysis																			
"	"	" " "	Dakota	II	--	--	19	20	22	24	25	26	31	29	31	33	37	34.8	-.10	52	1.3	17.0	PI	34-043
"	"	" " "	Lakota		No Analysis																			
Jurassic	Colorado	Iles	Morrison	II	--	19	20	20	22	25	27	28	35	34	36	37	38	32.5	-.10	59	3.0	14.8	I	37-031
"	"	"	Sundance	II	--	17	17	17	20	23	27	30	40	39	41	43	43	31.2	-.10	63	3.6	14.8	I	35-026
"	"	Moffat	Sundance	II	15	16	15	17	19	20	22	23	31	29	30	31	31	38.0	-.10	44	2.4	24.9	P	37-035
"	"	Wilson Creek	Morrison	II	14	19	20	21	21	21	22	24	32	30	30	31	32	49.2	-.10	33	0.7	47.6	P	38-022
"	"	" "	Sundance	II	14	17	15	20	20	21	23	25	34	32	32	32	34	48.1	-.10	34	0.8	47.1	PI	41-035
"	Montana	Bannatyne	Embar		Incomplete Analysis													23.7	2.34	147	-	12.5	I	31-07
"	"	Kevin-Sunburst	Ellis stray	II-VI	21	20	21	24	25	27	29	31	--	40	44	46	47	36.0	0.36	39	1.5	29.1	I	43-051
"	Wyoming	Big Medicine Bow	First Sundance	V	12	17	18	19	19	16	16	16	--	--	--	--	--	63.4	-.10	-32	Tr.	74.5	P	39-036
"	"	" " "	Second Sundance	V	13	18	20	20	20	19	18	18	--	--	--	--	--	63.1	-.10	-32	Tr.	78.0	P	37-09
"	"	Bolton Creek	Sundance	VI	--	15	19	23	26	29	31	34	40	37	43	47	50	21.6	2.31	330	10.2	10.2	I	*30-31
"	"	Byron	Sundance		No Analysis																			
"	"	Ferris	Sundance		No Analysis																			
"	"	Lance Creek	Upper Sundance	II	21	20	20	21	21	21	22	23	30	28	28	30	31	38.0	-.10	43	1.1	30.1	P	37-06
"	"	" "	Basal Sundance	II	13	17	19	20	20	19	20	21	30	28	28	29	31	46.9	-.10	33	0.6	44.1	P	37-08
"	"	Lost Soldier	Morrison	IV	--	--	35	40	43	45	45	42	38	34	32	32	33	28.8	0.15	86	1.8	8.8	I	33-014
"	"	" "	Sundance	IV	--	--	36	41	43	46	46	43	39	35	34	34	35	28.2	0.23	89	1.7	7.7	I	36-017
"	"	x Poison Spider	Lower Sundance	VI	--	--	--	--	--	21	27	32	--	--	49	51	53	22.0	2.75	263	6.8	13.1	I	40-01
"	"	Quealy	Sundance		Incomplete Analysis													32.4	0.34	-	-	24.4	-	*
"	"	Rock Creek	Sundance	II	19	23	23	22	23	24	26	28	37	34	34	36	38	37.2	-.10	43	3.0	29.0	I	36-02
"	"	Salt Creek	Morrison	II	--	--	28	29	29	30	31	32	35	34	34	36	37	30.2	-.10	85	3.4	17.1	I	37-043
"	"	" "	Second Sundance	II	27	25	24	25	26	26	27	29	--	33	33	34	36	35.0	-.10	48	2.8	25.3	I	43-040
"	"	" "	Third Sundance	II	21	23	25	27	28	30	31	31	36	32	32	34	35	36.0	0.27	45	2.5	26.9	I	34-051
"	"	x Spindletop	Sundance	VI	--	--	--	24	28	31	34	36	--	42	46	50	53	19.8	3.26	458	8.2	6.9	I	43-06
pre-Jur.	Colorado	Rangely	Weber	II-VI	28	25	23	26	27	28	31	33	39	37	43	44	46	32.5	0.68	52	2.9	22.4	I	33-07
"	Montana	Cedar Creek	Madison	II-VI	--	21	18	16	16	17	19	22	--	32	37	42	47	26.6	0.93	71	6.5	15.9	PI	42-036
"	"	" "	Bighorn (?)	II-VI	21	15	10	8	9	10	13	15	28	29	34	40	45	28.2	0.62	99	8.5	18.3	PI	37-058
"	"	Devils Basin	Van Duzen	II-VI	--	--	34	35	35	34	35	38	43	43	45	49	52	22.3	1.51	285	3.7	6.3	I	36-028
"	"	Frannie	Tensleep		See Wyoming																			
"	"	Kevin-Sunburst (N)	Madison	II-VI	--	30	28	28	29	30	31	33	40	37	40	42	45	37.4	0.59	36	1.8	31.4	I	41-048
"	"	" "	Madison	II-VI	--	20	19	21	24	27	30	33	47	45	47	50	51	31.1	1.17	50	2.6	21.5	I	36-027
"	"	Pondera	Madison	II-VI	17	18	21	24	25	26	27	31	43	41	43	48	50	32.7	1.80	47	4.8	30.9	I	38-014
"	"	Soap Creek	Tensleep	VI	--	--	--	31	29	31	33	40	48	46	50	54	56	17.5	3.73	716	8.7	6.5	I	34-042
"	"	" "	Amsden	VI	--	--	18	19	24	27	31	35	47	45	50	55	57	16.6	3.92	575	9.2	8.4	I	34-040
"	"	Twin Rivers(Reagan)	Madison	II-VI	25	25	26	28	27	27	29	31	41	39	43	44	45	36.4	0.74	39	1.3	31.9	I	43-018
"	Utah	San Juan	Goodridge	II	21	25	28	30	31	31	32	33	37	34	34	37	38	39.0	0.24	31	2.1	32.9	I	33-032
"	"	Virgin	Moenkopi	II	28	26	24	23	24	25	26	28	37	35	37	40	41	30.8	0.83	67	4.9	19.7	I	37-013
"	Wyoming	Black Mountain	Embar	VI	--	17	17	20	21	25	28	32	--	45	49	54	58	25.9	2.71	109	3.3	17.7	I	40-042
"	"	" "	Tensleep	VI	--	19	17	14	15	18	21	27	40	40	45	50	55	22.8	2.85	200	4.8	6.8	PI	40-041
"	"	Bolton Creek	Embar	VI	9	5	15	14	23	26	29	32	41	40	43	48	51	31.9	2.32	51	5.8	24.2	I	35-021
"	"	Byron	Embar	VI	--	--	--	--	15	19	23	30	--	46	48	52	56	18.1	3.12	1155	9.3	7.7	I	40-046
"	"	"	Tensleep	VI	--	--	--	--	20	24	28	34	--	46	50	54	56	24.0	1.75	156	7.8	11.8	I	43-045
"	"	Circle Ridge	Embar	VI	--	--	21	21	21	24	29	33	44	45	49	53	57	23.3	2.83	155	7.3	11.2	I	42-028
"	"	" "	Tensleep	VI	--	--	20	19	21	25	29	33	--	44	50	54	57	23.8	2.76	124	7.3	11.6	I	42-046
"	"	Crystal Creek	Tensleep	VI	--	--	--	--	--	29	33	37	--	49	51	55	60	17.1	4.04	5000+	4.0	3.1	I	39-022
"	"	Dallas	Chugwater		No Analysis																			
"	"	"	Embar	VI	--	--	--	--	--	30	33	37	--	41	46	49	56	20.5	2.31	318	7.8	8.2	I	42-039
"	"	"	Tensleep	VI	--	--	--	--	21	23	29	37	--	46	52	57	60	20.0	2.77	370	9.4	7.2	I	42-042
"	"	Derby	Embar	VI	--	--	15	19	22	26	29	33	40	39	47	52	56	21.0	2.73	308	9.4	6.5	I	*24-329
"	"	"	Tensleep	VI	--	--	25	20	19	21	23	28	41	40	43	47	50	23.8	2.69	223	2.6	7.6	I	40-040
"	"	Dewey	Minnelusa	VI	31	28	28	29	30	32	35	39	48	49	54	58	60	31.7	1.17	40	2.6	31.6	UI	37-066
"	"	East Mahoney	Tensleep	II-VI	14	15	13	14	15	19	22	24	37	35	39	44	48	43.8	0.58	35	1.6	42.8	PI	40-039
"	"	Elk Basin	Tensleep	VI	19	20	24	26	27	26	32	36	--	47	51	55	57	29.9	1.66	52	4.6	24.9	I	43-030
"	"	Ferris	Chugwater (Parco)		No Analysis																			
"	"	Fourbear	Tensleep	VI	--	--	--	--	--	26	34	39	--	49	51	58	62	13.5	3.88	6000+	13.3	2.3	IN	*30-20
"	"	Frannie	Tensleep	VI	--	14	15	18	20	24	27	33	48	49	53	56	58	27.9	2.36	74	4.8	19.1	I	40-044
"	"	"	Madison	VI	--	--	--	--	28	26	27	31	43	43	47	53	59	17.3	3.07	937	6.5	0.8	I	40-043
"	"	Garland	Tensleep	VI	--	--	--	20	24	26	27	29	39	42	46	52	56	21.3	2.55	215	5.9	8.0	I	36-013
"	"	"	Madison	VI	--	--	19	22	25	28	31	36	48	46	51	57	60	20.7	3.27	427	6.9	9.9	I	34-022

23521

CRUDE OILS OF THE ROCKY MOUNTAIN REGION

GEOLOGIC SYSTEM	STATE	FIELD	PRODUCTIVE ZONE	TYPE OF* OIL	CORRELATION INDEX NUMBERS 3	4	5	6	7	8	9	10	11	12	13	14	15	GRAVITY °A.P.I.	SULFUR PERCENT	S U V AT 100°F SECS.	CARBON RESIDUE PERCENT	TOTAL GASOLINE PERCENT	BASE OF CRUDE	LABOR-ATORY NUMBER
pre-Jur.	Wyoming	Gooseberry	Embar	VI	--	--	--	26	24	24	26	31	44	42	46	50	54	22.5	1.93	180	3.7	9.1	I	38-05
"	"	"	Tensleep	VI	--	--	--	22	21	22	25	30	48	46	47	52	56	21.5	2.31	258	2.9	9.6	I	38-02
"	"	Grass Creek	Chugwater	VI	20	16	16	18	19	24	27	33	--	46	50	55	58	24.7	2.31	126	9.0	16.7	I	43-023
"	"	" "	Embar	VI	19	14	12	15	19	24	25	29	43	42	46	52	56	24.5	2.54	110	3.8	16.1	I	37-012
"	"	" "	Tensleep		Not segregated																			
"	"	Hamilton Dome	Chugwater (Curtis)	VI	--	--	--	19	19	19	23	28	--	42	46	51	55	20.0	3.12	414	4.3	8.9	I	39-023
"	"	" "	Embar	VI	--	--	--	--	17	18	22	25	--	40	47	51	56	21.1	3.02	320	6.4	8.8	PI	39-010
"	"	" " (edge)	Embar	VI	--	--	--	--	--	--	29	33	--	47	52	57	61	15.7	3.58	3720	4.7	2.0	IN	40-010
"	"	" "	Tensleep	VI	--	--	--	--	16	18	22	27	--	40	46	52	55	20.8	3.03	325	4.5	8.2	PI	39-026
"	"	Lake Creek	Embar	VI	--	--	30	34	37	37	41	42	--	46	51	55	56	22.3	3.17	175	6.8	15.5	I	*30-23
"	"	Lance Creek	Converse	II	15	16	17	17	18	18	20	21	30	28	28	28	29	42.1	-.10	47	1.2	36.3	P	38-018
"	"	" "	First Leo	II	20	19	19	21	20	20	22	22	30	27	28	29	31	42.1	-.10	38	1.1	36.2	P	43-010
"	"	" "	Second Leo	II	19	20	20	20	20	20	22	23	30	28	28	29	30	41.7	-.10	39	1.2	34.4	P	43-09
"	"	" "	Third Leo	II	--	22	21	22	21	22	23	24	30	27	28	29	30	40.0	-.10	39	1.2	31.7	P	43-08
"	"	" "	Fourth Leo	II	18	19	20	20	20	21	23	24	30	28	29	29	31	42.6	-.10	37	1.1	36.4	P	43-07
"	"	x Lander (Hudson)	Embar	VI	--	--	--	--	15	19	22	27	41	40	45	49	55	24.0	2.80	159	5.6	6.5	PI	40-045
"	"	" "	Tensleep	VI	--	--	--	21	25	26	29	32	39	37	43	49	55	21.8	3.00	284	5.7	7.7	I	33-019
"	"	Lost Soldier	Tensleep	VI	13	13	16	19	21	23	25	30	44	42	45	48	51	35.2	1.05	41	3.6	29.5	I	36-014
"	"	Mahoney (West)	Tensleep	VI	--	18	16	16	17	20	23	26	40	39	42	46	49	34.2	1.32	48	3.2	25.4	PI	39-019
"	"	Maverick Springs	Embar	VI	--	--	25	21	24	27	31	33	41	41	47	53	56	21.5	3.03	330	6.5	7.4	I	34-04
"	"	Mule Creek (East)	Leo	VI	--	14	17	21	25	29	33	37	51	51	55	60	64	26.6	2.41	70	4.9	18.8	IN	35-015
"	"	North Casper Creek	Tensleep	VI	--	--	--	--	--	24	26	28	--	37	40	45	50	21.5	2.81	234	9.4	6.3	I	42-019
"	"	North Oregon Basin	Embar	VI	--	--	21	21	23	26	30	36	--	54	55	58	61	22.8	2.91	177	7.4	15.3	IN	43-038
"	"	" " "	Tensleep	VI	--	--	19	20	23	25	29	34	--	51	53	58	60	23.1	2.77	154	6.1	14.2	I	43-037
"	"	x North Sunshine	Tensleep	VI	--	--	--	--	28	34	39	45	--	52	55	58	62	14.7	3.74	4000	11.6	5.3	N	*30-18
"	"	Notches	Tensleep	VI	--	--	--	--	--	30	32	34	44	43	48	51	54	22.0	1.63	293	7.7	4.3	I	42-014
"	"	Pilot Butte	Embar	VI	--	--	--	--	25	29	32	36	47	46	50	53	55	22.3	2.54	155	7.8	6.7	I	43-011
"	"	" "	Tensleep	VI	--	15	17	19	22	25	29	35	48	46	50	54	57	26.1	2.34	88	8.6	18.4	I	43-016
"	"	Pine Mountain	Embar	VI	--	--	--	--	--	--	--	47	--	52	53	56	58	18.7	0.17	1375	6.8	0	NI	42-020
"	"	Pitchfork	Embar-Tensleep	VI	--	--	--	--	31	35	41	43	--	49	54	53	61	15.7	3.87	2580	9.9	6.3	IN	*30-34
"	"	Red Springs	Madison	VI	--	--	--	--	--	--	--	--	--	--	61	67	70	11.4	4.42	5000+	5.3	0	IN	40-053
"	"	Rocky Ford	Minnelusa	VI	--	--	--	25	32	35	40	43	50	52	55	59	63	15.0	4.19	1155	3.7	6.6	IN	34-028
"	"	Sage Creek	Chugwater	VI	--	--	--	--	20	26	30	34	48	47	51	55	58	21.3	3.39	214	5.7	10.8	I	40-07
"	"	Salt Creek	Tensleep	VI	--	12	15	16	17	18	20	23	37	35	38	43	47	27.1	2.24	98	6.5	13.5	PI	37-042
"	"	Sheep Creek	Embar	VI	--	10	13	13	17	27	32	35	45	45	48	51	54	22.8	2.78	152	8.8	10.6	I	35-023
"	"	Shoshone	Embar	VI	--	--	22	23	24	27	30	36	--	50	54	58	61	18.6	3.41	793	3.7	11.5	IN	39-02
"	"	"	Embar-Tensleep	VI	--	--	--	--	--	--	30	40	--	54	57	60	64	18.9	3.64	515	7.9	12.7	IN	42-050
"	"	South Casper Creek	Tensleep	VI	--	--	--	--	--	27	34	40	--	56	61	65	67	15.7	4.43	890	4.0	4.8	IN	40-02
"	"	South Oregon Basin	Embar	VI	17	15	16	17	19	22	27	33	48	48	53	58	61	20.7	3.20	326	9.1	14.0	IN	37-015
"	"	" " "	Tensleep	VI	--	15	16	18	20	23	26	35	--	--	51	56	60	20.5	3.33	348	7.9	13.5	I	38-027
"	"	x South Spring Creek	Embar-Tp-Amsden	VI	--	14	10	14	21	28	36	42	--	45	55	60	65	15.4	4.04	3010	11.8	7.2	IN	*37-L39
"	"	South Sunshine	Embar	VI	--	--	--	--	29	32	36	38	45	44	49	53	56	17.9	3.15	1110	10.5	6.2	I	*30-19
"	"	Warm Springs	Embar	VI	--	--	--	14	16	24	30	33	43	46	49	54	57	17.8	3.47	745	9.1	2.7	I	35-01
"	"	Waugh Dome	Embar	VI	--	16	16	16	20	24	27	29	40	40	46	50	52	27.7	1.74	73	3.1	16.8	I	35-016
"	"	Wertz	Tensleep	VI	11	11	14	16	18	19	22	26	42	42	45	49	52	35.4	1.31	41	2.6	28.5	PI	37-060
"	"	West Mule Creek	Bell	VI	14	14	17	20	23	26	29	33	47	45	47	52	57	34.2	1.02	42	4.8	31.7	I	36-023

* under laboratory number refers to analyses other than by the Geological Survey.

Base of crude: P, paraffin; IP, intermediate-paraffin; PI, paraffin-intermediate; I, intermediate; IN, intermediate-naphthene; NI, naphthene-intermediate; N, naphthene.

x ADDENDA.

GEOLOGIC SYSTEM	STATE	FIELD	PRODUCTIVE ZONE	TYPE OF* OIL	3	4	5	6	7	8	9	10	11	12	13	14	15	GRAVITY °A.P.I.	SULFUR PERCENT	S U V AT 100°F SECS.	CARBON RESIDUE PERCENT	TOTAL GASOLINE PERCENT	BASE OF CRUDE	LABOR-ATORY NUMBER
Cretaceous	Wyoming	Steamboat Butte	Dakota	II	21	23	24	25	24	25	26	27	35	32	32	34	37	42.6	-.10	35	0.7	40.1	PI	43-049
"	"	" "	Lakota	II	21	23	25	26	27	29	29	32	--	35	37	39	41	40.0	-.10	40	1.0	36.6	I	43-058
Jurassic	"	North Baxter Basin	Morrison (?)	II	15	17	18	20	21	25	26	30	--	37	38	40	42	41.1	0.63	37	1.4	38.7	I	42-027
"	"	Steamboat Butte	Sundance	VI	--	19	19	21	23	26	29	33	--	45	49	52	53	27.7	2.30	78	7.0	21.0	I	43-057
pre-Jur.	"	Lance Creek	Bell	II	17	22	23	24	23	23	25	25	--	27	27	27	28	44.9	-.10	36	0.8	40.4	P	43-070
"	"	South Oregon Basin	Madison	VI	--	--	--	--	--	27	33	39	--	--	54	58	62	17.8	2.92	910	7.4	10.9	IN	43-054

23521

Table II, Sheet IV

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 10 (OCTOBER, 1943), PP. 1335-1360, 4 FIGS.

STRATIGRAPHY AND PALEONTOLOGY OF SANTA MARIA DISTRICT, CALIFORNIA[1]

W. P. WOODRING,[2] M. N. BRAMLETTE,[3] AND K. E. LOHMAN[2]
Washington D. C., and Los Angeles, California

ABSTRACT

Nine producing or potentially productive oil fields or areas are located in the Santa Maria district, which lies in the Santa Maria basin in coastal California. Formations in outcrop and subsurface sections range in age from Jurassic(?) to Recent. They have a maximum outcrop thickness of about 13,000 feet. The Monterey shale (middle to upper Miocene) and the Sisquoc formation (upper Miocene (?) to middle Pliocene) are the formations of greatest economic interest, the principal oil zones of the largest fields being in fractured chert and cherty shale of the Monterey. The basin facies of the Sisquoc formation represents a Monterey-like facies of later date than the Monterey proper. The stratigraphic relations of the Sisquoc formation and of overlying Pliocene formations show a close correlation with structural features and structural history. Deformation took place at the eastern margin of the basin and on anticlines in the basin during late Miocene and Pliocene time. Most of the present anticlines were evidently then growing ridges on the floor of the sea and the present synclines were basins. The principal deformation, affecting the entire region, took place after deposition of the non-marine Paso Robles formation (upper Pliocene to lower Pleistocene (?)).

INTRODUCTION

Oil has been produced in the Santa Maria district since 1903. Interest in the district was greatly stimulated by the discovery of oil in the Santa Maria Valley in 1934 and by subsequent development, which soon showed that the Santa Maria Valley field is a major field. Owing to the present demand for heavy oil, the Santa Maria district, one of the principal sources of heavy oil in California, is receiving special consideration. As shown in Figure 1, the district includes 9 producing or potentially productive fields or areas, the largest in area and productive capacity being the Santa Maria Valley field.

During the period from 1938 to 1940 an area of about 400 square miles in the Santa Maria district was mapped by W. P. Woodring and M. N. Bramlette with the assistance of K. E. Lohman and R. P. Bryson, under the auspices of the United States Geological Survey. Completion of the report embodying the results of this field work has been interrupted by the war program of the Geological Survey. Inasmuch as the production of heavy oil is an essential war requirement, the present preliminary report is offered as a summary of the stratigraphic and paleontologic results, which may be of some use in the further search for heavy oil in the district.

Figure 1 is a small-scale generalized geologic map of the area mapped.

The subsurface data included in the present report are based principally on published descriptions and on information from resident geologists. Particular acknowledgment is due to geologists of the Union Oil Company of California.

[1] Manuscript received, May 10, 1943. Published with the permission of the director of the United States Geological Survey.

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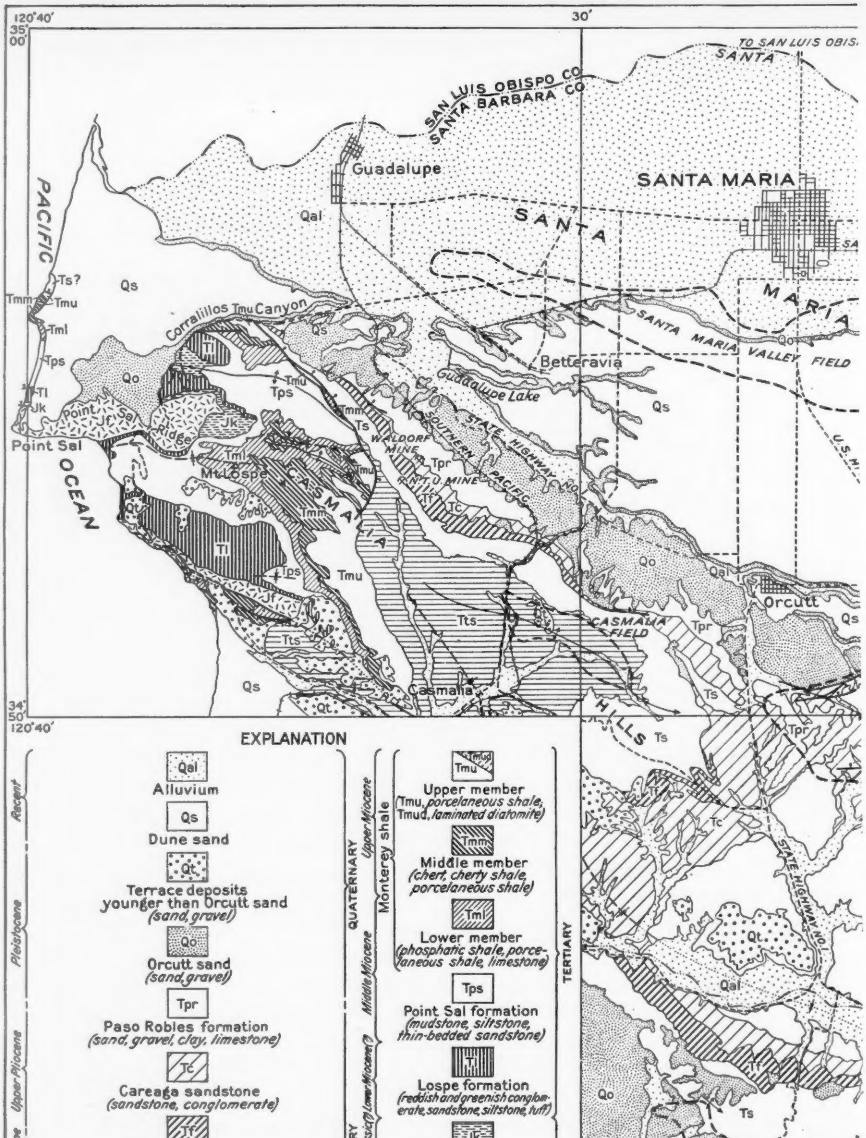
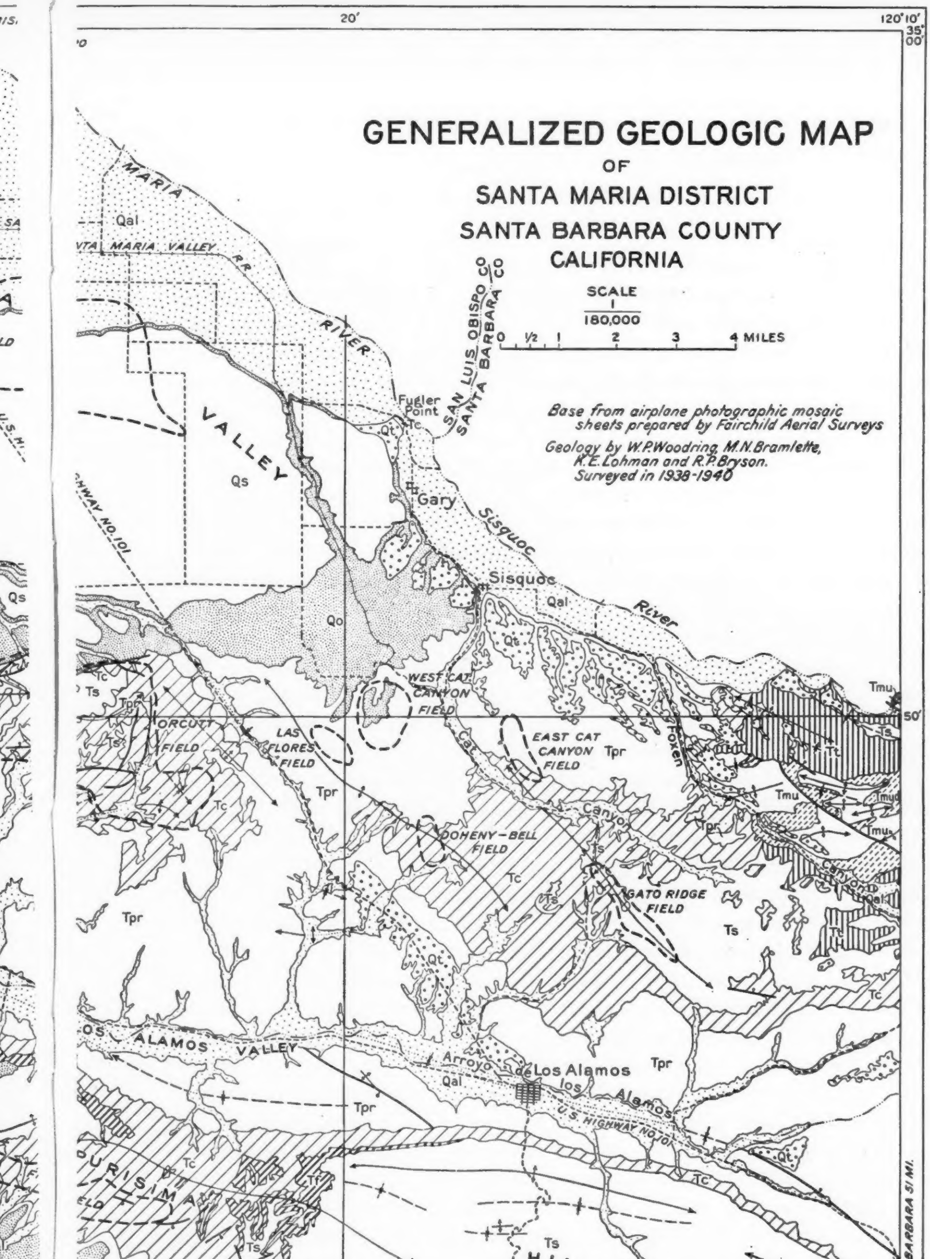


FIG. 1.—Generalized geologic map of Santa Maria district, California.


GENERALIZED GEOLOGIC MAP
OF
SANTA MARIA DISTRICT
SANTA BARBARA COUNTY
CALIFORNIA
SCALE
1/180,000
0 1/2 1 2 3 4 MILES
Base from airplane photographic mosaic sheets prepared by Fairchild Aerial Surveys
Geology by W.P. Woodring, M.N. Bramlette, K.E. Lohman and R.P. Bryson.
Surveyed in 1938-1940
SAN LUIS OBISPO CO
SANTA BARBARA CO
20'
120°10'
35° 00'
50'
34° 40'
MARIA RIVER
VALLEY
Fugler Point
Gary
Sisquoc
Sisquoc River
WEST CAT CANYON FIELD
EAST CAT CANYON FIELD
LAS FLORES FIELD
ORCUTT FIELD
DOHENY-BELL FIELD
GATO RIDGE FIELD
Cat Canyon
Foxen Canyon
LOS ALAMOS VALLEY
Arroyo de Los Alamos
Los Alamos
U.S. HIGHWAY NO. 101
HIGHWAY NO. 101
PURISIMA
MISSION PURISIMA
HILLS
Redrock Mtn
TO SANTA BARBARA 51 MI.
Qal
Qs
Qo
Qt
Tpr
Tc
Ts
Tsd
Tmu
Tmud

ornia.

The Foraminifera were identified by M. N. Bramlette, the diatoms by K. E. Lohman, and the megafossils by W. P. Woodring.

SUMMARY OF STRATIGRAPHY AND GEOLOGIC HISTORY

The Santa Maria district lies in the Santa Maria basin, a triangular lowland widening seaward between the westward-trending Santa Ynez Range and the northwestward-trending San Rafael Range and Santa Lucia Range. This triangular lowland corresponds with a structural basin and with the northern part of a late Tertiary and Pleistocene depositional basin. As pointed out by Reed and Hollister,[4] the Santa Maria Valley at the north border of the basin is the boundary between two geologic provinces. North and northeast in the Santa Lucia Range and San Rafael Range the valleys and hills are either synclines or anticlines. South in the Santa Maria basin major valleys coincide generally with major synclines and the hills are anticlinal, that is, as in other California late Tertiary and Pleistocene basins, the last period of deformation was so recent that in general the topography reflects faithfully the structure. Santa Maria Valley itself is a syncline. It is, however, unlike valleys farther south, as the axis of the syncline is not in the middle of the valley, but is far to the south close to the bordering hills or locally even within the hills. The geologic map (Fig. 1) does not include the southern and extreme eastern parts of the Santa Maria basin.

The stratigraphy of the Santa Maria district is summarized in Table I. The oldest rocks are of Franciscan (Jurassic (?)) age. They crop out only along and near the coast in the Point Sal area, where so far as known they consist of igneous rocks. In part of the Point Sal area the Franciscan is overlain by the Knoxville formation, which consists principally of shale and contains fossils indicating late Jurassic (?) age. In the subsurface section in the Santa Maria Valley field strata of uncertain age, doubtless late Jurassic or Cretaceous, are included with the Franciscan in the basement. During early Tertiary time, and also perhaps during Cretaceous time, at least most of the Santa Maria district was an emerged upland. Cretaceous and early Tertiary formations are not represented in the outcrop section and are not identified certainly in subsurface sections.

The history of the Santa Maria district as part of a depositional basin begins in the early Miocene (?), when the non-marine, apparently non-fossiliferous strata of the Lospe formation were deposited. These non-marine strata crop out in the Point Sal area, where they rest on Knoxville or Franciscan. They have been penetrated in the Casmalia and Orcutt fields, but are not represented in the Santa Maria Valley field. The Lospe formation is probably the non-marine equivalent of the lower Miocene Vaqueros formation, which crops out in the bordering mountains.

The sea first penetrated most of the Santa Maria district during middle Miocene time. At that time the mudstone of the Point Sal formation was deposited.

[4] R. D. Reed and J. S. Hollister, *Structural Evolution of Southern California*, Amer. Assoc. Petrol. Geol. (1936), pp. 92–94.

In the Point Sal area the Point Sal formation overlies the Lospe formation or appears to overlap it and to rest on Knoxville or Franciscan. The Point Sal sea did not reach, however, the north border of the basin, or if it extended so far north the sediments then laid down were removed before the next younger formation was deposited. The Point Sal formation is overlain by the Monterey shale, of middle to late Miocene age, the earliest widespread formation in both outcrop and subsurface sections and economically the most important, as it includes the principal oil zones of the largest fields. The Monterey consists of three mapped members and as in other Coast Range districts is characterized by hard porcelaneous and cherty shale and by soft diatomaceous strata. In the Santa Maria Valley field the Monterey overlaps the basement. In the East Cat Canyon field it is thin and incomplete.

The Monterey is overlain by the Sisquoc formation, which overlies the Monterey conformably or unconformably and includes strata of different facies. Both stratigraphic relations and facies are closely related to structural features and structural history. In the central part of the basin, where the sediments are thickest, the Sisquoc formation consists of fine-grained, dominantly diatomaceous sediments—the basin facies. The lower half of the basin facies in the Casmalia Hills, characterized by somewhat porcelaneous claystone, is designated the Todos Santos claystone member. A marginal facies on the eastern border of the basin is made up principally of sandstone, the Tinaquaic sandstone member, which grades basinward into the basin facies. On the eastern and northern border of the basin and on most of the anticlines in the basin the Monterey was deformed before the Sisquoc was deposited and in those areas the Sisquoc rests discordantly on the Monterey. At the extreme north edge of the basin the Sisquoc overlaps completely the Monterey and rests on the basement. In synclines within the basin, where no deformation took place, the basin facies of the Sisquoc conformably overlies the Monterey and represents a continuation of Monterey type of sediments. The Sisquoc formation is of late Miocene (?) to middle Pliocene age. The lower half includes one or more oil zones, the only productive zones in several minor fields.

In complete synclinal sections the Foxen mudstone, consisting principally of mudstone and siltstone, overlies gradationally the Sisquoc formation. Anticlines within the basin were evidently growing during Foxen time, for the Foxen is thin or absent on them, and is missing at the eastern border of the basin. The upper part of the Foxen mudstone is assigned to the upper Pliocene; the lower part is probably middle Pliocene.

The next younger formation, the Careaga sandstone, is of late Pliocene age. It is subdivided into a lower member made up of fine-grained sandstone and an upper member consisting of coarse-grained sandstone and conglomerate, designated, respectively, the Cebada fine-grained member and the Graciosa coarse-grained member. In complete sections the Cebada member overlies gradationally the Foxen mudstone. In most of the areas where the Foxen is missing the Cebada

TABLE I
FORMATIONS OF SANTA MARIA DISTRICT

Age	*Formation*	*Member*	*Outcrop Thickness, in Feet*	*Lithology*	*Important Fossils*
Recent	Dune sand		10–100	Well-sorted strongly cross-bedded sand	
Upper Pleistocene	Terrace deposits younger than Orcutt sand		25–100	Marine sand and gravel, a foot to 6 feet thick, on platform of marine terraces. Reddish brown sand, gravel, and rubble forming nonmarine cover on marine terraces. Sand and gravel on stream terraces	
Upper Pleistocene	Orcutt sand		25–100	Reddish brown sand, gravel	
Upper Pliocene to lower Pleistocene(?)	Paso Robles formation		2,000±	Sand, gravel, clay, limestone	Fresh-water mollusks and ostracodes
Upper Pliocene	Careaga sandstone	Graciosa coarse-grained member	25–425	Coarse-grained sandstone, conglomerate	*Dendraster ashleyi, Patinopecten healeyi, Lyropecten cerrosensis, Pseudocardium* cf. *densatum*
		Cebada fine-grained member	0–1,000	Fine-grained sandstone	*Patinopecten healeyi, Lyropecten cerrosensis*
Middle (?) to upper Pliocene	Foxen mudstone		0–800	Mudstone, siltstone, fine-grained sandstone	*Bolivina* aff. *obliqua, B.* aff. *tumida, Uvigerina "foxeni," Virgulina californiensis* var. *Podosira montagnei, Stephanopyxis turris* var. *cylindrus, Coscinodiscus asteromphalus, C. cirrus, Xanthiopyxis ovalis* *Dendraster (Merriamaster)* cf. *perrini, Patinopecten healeyi, P. dilleri*
Upper Miocene (?) to middle Pliocene	Sisquoc formation	Tinaquaic sandstone member (marginal facies)	350–1,400	Sandstone, conglomerate, siltstone	*Elphidiella hannai, Nonion belridgensis* *Coscinodiscus* aff. *excentricus, C. obscurus, Lithodesmium minusculum, Rhaphoneis angularis Fragilaria ischaboensis* *Dendraster* cf. *coalingaensis, Patinopecten lohri, Pseudocardium* cf. *densatum*

Age	Formation	Member	Outcrop Thickness, in Feet	Lithology	Important Fossils
		Diatomaceous strata and Todos Santos claystone member (basin facies)	150–3,000	Diatomaceous mudstone, clayey less diatomaceous mudstone, laminated diatomite, somewhat porcelaneous mudstone, somewhat porcelaneous claystone, porcelaneous shale	*Bolivina obliqua, B. rankini, B. ticensis, Nonion belridgensis, Nonionella miocenica* var., *Virgulina californiensis* *Melosira recedens, Endictya tubiformis, Coscinodiscus aeginensis, C. intersectus, Lithodesmium cornigerum* *Nuculana* sp., *Patinopecten dilleri, Patinopectin lohri?*
		Upper member	600–1,000	Porcelaneous shale, laminated diatomite	*Cassidulinella renulinaformis, Ellipsoglandulina* sp., *Hopkinsina* sp. *Coscinodiscus gigas, C. oculis-iridis* var. *borealis, Asterolampra marylandica, Lithodesmium californicum, Goniothecium rogersii*
Middle to upper Miocene	Monterey shale	Middle member	185–225	Chert, cherty shale, porcelaneous shale	
		Lower member	200–900	Phosphatic shale, silty shale, somewhat porcelaneous shale	*Anomalina salinasensis, Pullenia miocenica, Siphogenerina collomi, S. reedi, S. branneri*
Middle Miocene	Point Sal formation		150–1,500	Mudstone, siltstone, thin beds of sandstone	*Siphogenerina hughesi* var., *Uvigerinella obesa, Valvulineria depressa, V. ornata*
Lower Miocene (?)	Lospe formation	Upper member	0–2,100	Greenish sandstone, greenish siltstone, greenish gypsiferous mudstone	
		Lower member	0–600	Reddish sandstone, reddish conglomerate	
Upper Jurassic (?)	Knoxville formation		0–500±	Shale, thin-bedded sandstone, conglomerate	*Aucella* cf. *piochii*
Jurassic (?)	Franciscan formation, igneous rocks			Basalt, gabbro, peridotite, serpentine	

member grades upward from the Sisquoc formation, indicating that the absence of the Foxen is not due to marked discontinuity but to deposition during Foxen time of a condensed section of fine-grained sand mapped with the Cebada. On the eastern border of the basin, however, the Cebada member overlaps the Sisquoc and rests discordantly on the Monterey. Likewise in most areas the Graciosa member overlies gradationally the Cebada member. On Graciosa anticline[5] in the Orcutt field the Graciosa member overlaps the Cebada and Foxen and rests on the Sisquoc formation. That anticline was growing evidently during Foxen and Cebada time. On the eastern margin of the basin the Graciosa member as well as the Cebada member overlies discordantly the Monterey.

During deposition of the Foxen mudstone and Careaga sandstone the basin was filled with marine sediments of decreasing depth facies, the Foxen and the Cebada fine-grained member of the Careaga representing in general water of moderate depth, the Graciosa coarse-grained member of the Careaga, shallow water. After the sea was filled with sediments, deposition still continued as the non-marine deposits of the Paso Robles formation were laid down. The age of the Paso Robles is uncertain. The lower part is presumably late Pliocene and the upper part is probably early Pleistocene. In the seaward part of the basin in both outcrop and subsurface sections the basal part of the Paso Robles includes thin marine tongues.

Strong deformation took place and the present structural features were formed after deposition of the Paso Robles formation. The deformation was followed by a relatively long period of erosion, during which an extensive surface sloping gently seaward was developed. Sand and gravel deposited on this surface are designated the Orcutt sand, which is presumably of late Pleistocene age. The sediments of the Orcutt sand may be regarded as terrace deposits, the oldest and most extensive terrace deposits in the district. They are tilted on the flanks of anticlines, evidently as a result of uplift of those folds. Other stream and marine terrace deposits, also presumably of late Pleistocene age, were deposited later, including deposits on five coastal marine terraces, the platform of the highest of which is at an altitude of about 850 feet.

After the emergence of most of the marine terraces and the development of corresponding stream terraces, soil, represented by widely distributed remnants of hardpan—the partial skeleton of the ancient soil profile—was formed on a surface of less relief than the present surface. Apparently during a still later period dune sand, now anchored by vegetation, was distributed far inland, particularly on the south border of Santa Maria Valley. The ancient soil and ancient dune sand, both evidently Recent, are not mentioned further. It should be pointed out, however, that the ancient hardpan, comprising Louderback's[6]

[5] Graciosa anticline and Graciosa Ridge are located in the northern part of the Orcutt field. The map (Fig. 1) is too congested to label them.

[6] G. D. Louderback, "Pseudostratification in Santa Barbara County, California," *Bull. California Univ. Dept. Geology*, Vol. 7 (1912), pp. 21–38, Pls. 3–6.

pseudostrata, is likely to be confusing to geologists unfamiliar with the district, as it may be mistaken for bedrock strata, particularly in areas underlain by gently dipping unconsolidated sand and gravel. It is parallel with the surface on which the ancient soil was formed and that surface may bear any relation to the dip of bedrock strata.

IGNEOUS ROCKS OF THE FRANCISCAN FORMATION

Igneous rocks of the Franciscan basement that crop out in the Point Sal area were described many years ago by Fairbanks.[7] They were examined only casually during the present investigation. So far as observed they consist principally of altered basalt and gabbro with minor areas of peridotite and serpentine.

KNOXVILLE FORMATION

The Knoxville formation overlies the Franciscan on the north slope of Point Sal Ridge. It is made up chiefly of dark-colored shale, but includes thin-bedded sandstone containing much mica and conglomerate characterized by small, smoothly polished and rounded black chert pebbles. At places the shale is altered to lustrous phyllite. The maximum outcrop thickness of the Knoxville is difficult to determine owing to minor folds, but is probably not more than 500 feet. In the subsurface section at the north border of the Casmalia Hills 2 miles east of the outcrop area it is 1,300 feet thick. It evidently thins rapidly westward toward the Franciscan of Point Sal Ridge, which presumably was a ridge, probably a submarine ridge, during Knoxville time.

The Knoxville of the Point Sal area contains a small slender *Aucella*, identified as *Aucella* cf. *piochii*. Elsewhere in the Coast Ranges Aucellae of that type are associated with ammonites of late Jurassic (Portlandian) age. In view of the meager evidence for the age of the Knoxville in the Point Sal outcrop area, it is considered of doubtful late Jurassic age. Sandstone and shale that contain a few Foraminifera and are included with the Franciscan formation in the basement of the Santa Maria Valley field[8] are of uncertain age, but are doubtless late Jurassic or Cretaceous.

LOSPE FORMATION

The recently named Lospe formation[9] overlies the Knoxville in the Point Sal area or overlaps it and rests on Franciscan. The thickness of the Lospe formation ranges from the vanishing point to a maximum of 2,700 feet, the thickest section being in the type region on the south slope of Mount Lospe. The Lospe formation consists of reddish and greenish nonmarine apparently non-fossiliferous strata. In most of the outcrop area it is subdivided into two mapped members, not

[7] H. W. Fairbanks, "Geology of Point Sal," *Bull. California Univ. Dept. Geol.*, Vol. 2 (1896), pp. 40–90.

[8] C. R. Canfield, "Subsurface Stratigraphy of Santa Maria Valley Oil Field and Adjacent Parts of Santa Maria Valley, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 67–68.

[9] S. G. Wissler and F. E. Dreyer, "Correlation of the Oil Fields of the Santa Maria District," *California Div. Mines Bull. 118*, Pt. 2 (1941), p. 237.

shown, however, on the generalized geologic map (Fig. 1). The lower member is characterized by reddish sandstone and reddish conglomerate. Much of the conglomerate is unsorted, unstratified, and includes angular slabs of local Franciscan rocks. The upper member consists of greenish sandstone, greenish gypsiferous siltstone, and greenish gypsiferous mudstone. The Lospe formation includes lenses of tuff that form conspicuous cliffs and have a maximum thickness of 60 feet. The tuff is hard white altered volcanic ash that at places shows relics of vitric shards.

The Lospe formation has been penetrated in the Casmalia and Orcutt fields. It is missing in the Santa Maria Valley field, but may be expected to be present in the trough of the syncline south of the field.

The Lospe formation is assigned to the lower Miocene (?). It is probably the nonmarine equivalent of the marine lower Miocene Vaqueros formation. Like the nonmarine Sespe formation of the southern Coast Ranges it may, however, include deposits of Oligocene or even Eocene age.

POINT SAL FORMATION

On the south slope of Mount Lospe the nonmarine Lospe formation is overlain conformably by marine mudstone and siltstone designated the Point Sal formation.[10] At other localities in the Point Sal area the Point Sal formation appears to overlap the Lospe and to rest on Knoxville or Franciscan. The thickness of the Point Sal formation ranges approximately from 150 to 1,500 feet, the thickest section being on the south slope of Mount Lospe, chosen as the type region. Made up chiefly of dark gray brown-weathering mudstone and siltstone, the Point Sal formation includes thin beds of sandstone and limestone concretions. Diabase sills are characteristic of the formation throughout much of the outcrop area.

The Point Sal formation has been penetrated in the Casmalia, Orcutt, and East Cat Canyon fields. It is represented in the southeastern part of the Santa Maria Valley field,[11] but is missing at the north and west. Sands in the upper part of the formation are productive in the southeastern part of the Santa Maria Valley field and in the Orcutt field.[12]

The Point Sal formation has a large foraminiferal fauna, including the following forms: *Baggina californica*, *Bolivina* aff. *cuneiformis*, *B. floridana*, *B. imbricata*, *B. marginata*, *B. salinasensis*, *B.* aff. *tumida*, *Buliminella subfusiformis*, *Globigerina bulloides*, *Nodogenerina advena*, *Nonion costiferum*, *Planulina* cf. *depressa*, *Plectofrondicularia* cf. *cookei*, *Pulvinulinella subperuviana*, *Robulus hughesi*, *R. reedi*, *Siphogenerina hughesi* var., *Uvigerinella obesa*, *Valvulineria depressa*, *V. ornata*, and *Virgulina californiensis*. The variety of *Siphogenerina hughesi*, which

[10] C. R. Canfield, *op. cit.* (1939), pp. 66–67, footnote.

[11] C. R. Canfield, *op. cit.* (1939), pp. 66–67.

[12] S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), p. 237.

shows numerous very fine costae, is associated elsewhere with the typical non-costate form of that species. The abundance of *Globigerina* suggests more open-sea conditions than for other formations of the district.

The fauna of the Point Sal formation belongs in the *Siphogenerina hughesi* zone, or the lower part of Kleinpell's Relizian stage, that is, early middle Miocene of current Coast Range chronology.

MONTEREY SHALE

The Monterey shale crops out in the western Casmalia Hills, the eastern Purisima Hills, and the Foxen Canyon-Sisquoc River area. It is represented in the subsurface section of fields in which wells deep enough to penetrate it have been drilled. The Monterey includes, in fact, the principal oil zones of the largest fields. In the western Casmalia Hills, the only region within the mapped area where the base of the formation is exposed, the Monterey overlies conformably the Point Sal formation and has an average thickness of about 1,500 feet. In the Santa Maria Valley field it overlaps northward onto the basement.

Three mapped members are recognized in the Monterey of the Santa Maria district. The lower member is characterized by phosphatic shale, silty shale, and somewhat porcelaneous shale; the middle member by chert, cherty shale, and porcelaneous shale; and the upper member by porcelaneous shale, or by porcelaneous shale and soft diatomaceous strata. The lower member is 200 to 900 feet thick in the western Casmalia Hills; the middle member has an average thickness of 200 feet; and the thickness of the upper member varies from 600 to 700 feet in the western Casmalia Hills and is about 1,000 feet in the eastern Purisima Hills. Limestone, doubtless more or less dolomitic and presumably not of primary origin, is found throughout the formation, being most abundant in the lower member. The chert of the middle member is characteristically contorted and forms generally conspicuous outcrops. Wherever the upper member includes both hard porcelaneous shale and soft diatomaceous strata, the soft diatomaceous strata overlie the hard porcelaneous shale. In the eastern Purisima Hills the soft diatomaceous strata at the top of the Monterey grade northwestward into hard porcelaneous shale, the change taking place at successively higher horizons northwestward.

In the Santa Maria Valley, Casmalia, Orcutt, Las Flores, Gato Ridge, and Lompoc fields the Monterey includes one to three oil zones.[13] The principal zone or zones in those fields are in fractured chert and cherty shale, corresponding lithologically with the middle member of the outcrop section. In the Santa Maria Valley field sand at the base of the formation is productive.

The lower member of the Monterey shale is middle Miocene in age, representing the upper part of the Relizian stage and all of the Luisian stage of Kleinpell. *Siphogenerina* is a conspicuous genus in the foraminiferal fauna, *S. branneri* being common in the lower part of the member and *S. collomi* in the upper part.

[13] S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), pp. 236–38, Fig. 95.

Other species from the lower member of the Monterey are as follows: *Anomalina salinasensis, Baggina robusta, Bolivina advena, B.* aff. *marginata adelaidana, Cassidulina panzana, Dentalina obliqua* (of Kleinpell), *Eponides rosaformis, Hemicristellaria beali, Nodogenerina advena, Planulina* aff. *ornata, Pullenia miocenica, Pulvinulinella subperuviana, Uvigerinella californica parva,* and *Valvulineria obesa.*

In the Casmalia Hills, the main outcrop area, the middle member of the Monterey is almost barren of Foraminifera. Small collections from the middle member in the eastern Purisima Hills indicate the lower part of Kleinpell's Mohnian stage (early upper Miocene). In subsurface sections chert beds, similar lithologically to chert of the middle member, are, from place to place, in different parts of the Mohnian, as pointed out by Dreyer and Wissler.[14] In the Santa Maria Valley and Gato Ridge fields the main chert beds are in the *Bolivina hughesi* zone, whereas in the Orcutt field they are in the older *Bulimina uvigerinaformis* and *Baggina californica* zones.

The upper member of the Monterey is almost barren of Foraminifera in the Casmalia Hills, but contains a large fauna in the eastern Purisima Hills. Common species are as follows: *Bolivina decurtata, Cassidulinella renulinaformis, Ellipsoglandulina* sp., *Hopkinsina* sp., *Planulina ornata, Pulvinulinella* aff. *capitanensis, Virgulina californiensis,* and *Virgulinella pertusa* (*V. miocenica* Cushman of Kleinpell). This fauna belongs in the upper part of the *Bolivina hughesi* zone. It represents also, however, in part a younger faunal division found in about 1,000 feet of strata between the *Bolivina hughesi* zone proper and the *Bolivina obliqua* zone in their type regions on the north side of the Santa Monica Mountains—strata thought to be virtually barren of Foraminifera when Kleinpell defined the *Bolivina hughesi* and *Bolivina obliqua* zones. The large and distinctive species of *Ellipsoglandulina, Hopkinsina,* and *Pulvinulinella,* still undescribed, are found in other areas, including the north slope of the Santa Monica Mountains, and seem to be restricted stratigraphically.

Limestone concretions from the upper member of the Monterey in the eastern Purisima Hills yielded a diatom flora of about 200 species characterized by *Coscinodiscus gigas* and the variety *diorama, C. oculus-iridis* var. *borealis, C. perforatus, Auliscus mirabilis, Asterolampra marylandica, Lithodesmium californicum, Goniothecium rogersii,* and *Campylodiscus montereyanus.* The species just mentioned are found in the type region of the Monterey shale and elsewhere in California in strata of late Miocene age. The Sisquoc formation and Foxen mudstone contain many large discoid diatoms of the genus *Coscinodiscus,* but forms as large as *Coscinodiscus gigas* and the variety *diorama* and *C. oculus-iridis* var. *borealis* are rare in those formations. Pelagic species are not abundant in the Monterey material from the Purisima Hills.

Megafossils are rare in the Monterey. A breccia-conglomerate in the lower

[14] S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), p. 236.

member exposed on the coast southeast of Point Sal contains fragments of *Aequipecten*, *Amusium*, *Ostrea*, and *Balanus*.

SISQUOC FORMATION, INCLUDING TINAQUAIC SANDSTONE MEMBER AND TODOS SANTOS CLAYSTONE MEMBER

The Sisquoc formation includes two principal facies: a fine-grained basin facies and a sandstone marginal facies represented at the eastern margin of the basin. The basin facies is made up dominantly of diatomaceous strata. When the formation was named[15] the marginal sandstone facies was emphasized. According to current usage, however, the term Sisquoc formation when unqualified refers to the basin facies, which is more extensive in both outcrop and subsurface sections. The marginal facies is designated the Tinaquaic sandstone member of the Sisquoc formation. Somewhat porcelaneous claystone forming about the lower half of the basin facies in the Casmalia Hills is named the Todos Santos claystone member of the Sisquoc formation. The type region of the Tinaquaic sandstone member is in the Foxen Canyon-Sisquoc River area; the type region of the Todos Santos claystone member is in the Casmalia Hills northwest of Casmalia.

Massive diatomaceous mudstone is the prevailing lithologic type in the basin facies. Though that type of lithology is more prevalent than in typical sections of the Monterey, the basin facies includes both soft diatomaceous and hard porcelaneous strata indistinguishable lithologically from those in the Monterey and represents essentially a Monterey-like facies. It was quite naturally, with few exceptions, assigned to the Monterey by Arnold and Anderson[16] during their early work in the Santa Maria district. In the Purisima Hills, where the basin facies overlies conformably the Monterey, it might be appropriate to consider the Sisquoc a member of the Monterey shale. In the Casmalia Hills, where a unit of distinctive lithology—the Todos Santos claystone member of the Sisquoc—separates the diatomaceous strata of the Sisquoc from the conformably underlying Monterey, and in the Foxen Canyon-Sisquoc River area, where the Tinaquaic sandstone member of the Sisquoc is unconformable on the Monterey (Fig. 2, C), assignment of the Sisquoc to the Monterey would be inappropriate.

Between Foxen Canyon and Sisquoc River the Tinaquaic sandstone member is 1,400 feet thick and rests unconformably on the Monterey. Consisting principally of sandstone, the Tinaquaic member includes diatom-bearing siltstone and conglomerate. In a syncline near Sisquoc River the Tinaquaic member grades upward into silty diatomaceous mudstone. The diatomaceous strata in the syncline are 225 feet thick, but the top of the formation is not exposed in that area. On the southwest side of Foxen Canyon the Tinaquaic member has a maximum

[15] W. W. Porter, II, "Lower Pliocene in Santa Maria District, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16 (1932), pp. 139–41.

[16] Ralph Arnold and Robert Anderson, "Geology and Oil Resources of the Santa Maria Oil District, Santa Barbara County, California," *U. S. Geol. Survey Bull. 322* (1907), pp. 36–52.

thickness of only 350 feet and overlies with marked unconformity the Monterey, the discordance being as much as 40° (Fig. 2, C). It grades upward into diatomaceous mudstone and clayey mudstone not more than 150 feet thick. The diatomaceous strata crop out westward to Gato Ridge, where the exposed thickness is about 250 feet. The subsurface section at Gato Ridge shows an additional thickness of 1,800 feet of strata assigned to the Sisquoc. The lower half of the subsurface section consists of siltstone and fine-grained sandstone interpreted as a westward-tapering tongue of the Tinaquaic member.

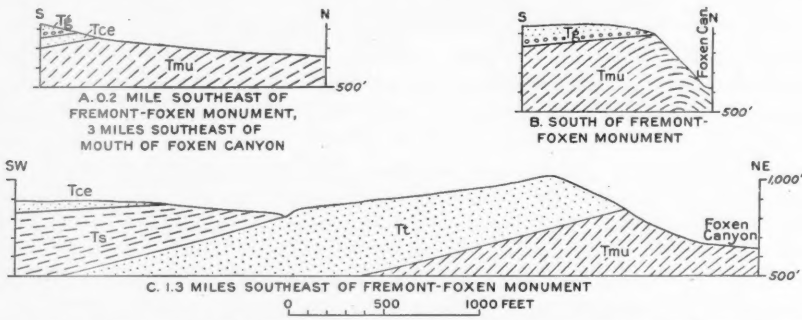


FIG. 2.—Stratigraphic relations of Sisquoc formation and Careaga sandstone in Foxen Canyon area.

Tg, Graciosa coarse-grained member of Careaga sandstone.
Tce, Cebada fine-grained member of Careaga sandstone.
Ts, Diatomaceous strata of Sisquoc formation.
Tt, Tinaquaic sandstone member of Sisquoc formation.
Tmu, Upper member of Monterey shale.

The Purisima Hills may be regarded as the type region of the basin facies of the Sisquoc formation. In that area the basin facies has an exposed maximum thickness of 3,000 feet. In the western and eastern parts of the hills it consists chiefly of soft diatomaceous mudstone and clayey less diatomaceous mudstone. In the central part of the hills it is made up almost entirely of fairly hard brownish somewhat porcelaneous mudstone in which diatoms are represented by molds. A light-colored "marker bed," about 400 feet below the top of the formation, shows clearly the change from soft diatomaceous to hard porcelaneous strata. In the southeastern part of the mapped area diatomite at the base of the formation grades northwestward into porcelaneous shale, the change taking place at progressively higher horizons northwestward. That is, the relations between diatomite and porcelaneous shale are the same as in the underlying Monterey. In part of that area diatomite at the base of the Sisquoc overlies lithologically indistinguishable diatomite at the top of the Monterey, or hard porcelaneous shale at the base of the Sisquoc overlies shale of the same type in the Monterey. The Foraminifera in the Monterey are so much larger than those in the Sisquoc that they may be readily differentiated in the field. A bed of silty strata, im-

pregnated with tar and containing scattered Franciscan and Monterey pebbles, phosphatic nodules, and vitric volcanic ash, is present locally at the base of the Sisquoc, indicating discontinuity.

In the Casmalia Hills the Sisquoc formation is 2,000 to 3,000 feet thick. The lower part, 1,500 feet thick, consisting of somewhat porcelaneous claystone and thin zones of platy porcelaneous or somewhat porcelaneous shale, is designated the Todos Santos claystone member. The porcelaneous shale in the upper member of the Monterey grades upward into the Todos Santos claystone member of the Sisquoc through the addition of somewhat porcelaneous claystone, the boundary between the formations being drawn at the base of the lowest thick claystone unit. The diatomaceous strata of the Sisquoc overlying the Todos Santos claystone member are 650 to 1,500 feet thick. The marked difference in thickness is due doubtless to lateral gradation of diatomaceous strata into non-diatomaceous and to varying thickness of a transition zone in which the ill defined boundary between the diatomaceous strata and the Todos Santos member is more or less arbitrarily placed. A zone of breccia-conglomerate and interbedded, sparsely diatomaceous, somewhat silty mudstone near the top of the formation extends southeastward from Corralillos Canyon in the western Casmalia Hills. The lenticular beds of breccia-conglomerate, as much as 60 feet thick, are made up of unsorted, poorly oriented angular slabs and chips of chert, cherty shale, and porcelaneous shale a fraction of an inch to a foot long, and a few pebbles of the same Monterey rock types. The thickness of the beds and the size of the constituents decreases southeastward, suggesting that the material was derived from the west, presumably west of the present coast, where the upper part of the Sisquoc is inferred to have overlapped onto the Monterey.

Sandy strata in the lower half of the Sisquoc formation contain oil in the Santa Maria Valley, Casmalia, Orcutt, Gato Ridge, and Lompoc fields, and constitute the only oil zone so far productive in the Doheny-Bell, West Cat Canyon, and East Cat Canyon fields.[17]

The Tinaquaic sandstone member of the Sisquoc contains a very meager foraminiferal fauna of shallow-water forms, such as *Elphidiella hannai* and *Nonion belridgensis*. The fauna of the more widespread basin facies of the Sisquoc, though of less shallow-water aspect, is nevertheless suggestive of the littoral to neritic zones. Common forms from the lower and middle parts of the basin facies include: *Bolivina obliqua*, *Buliminella curta*, *B. elegantissima*, *Eponides* sp., *Nonion belridgensis*, *N.* aff. *scapha*, *Nonionella miocenica*, a distinctive variety of that species, and *Virgulina californiensis*. Less common forms include: *Bolivina rankini*, *B. ticensis*, *Cassidulinoides cornuta*, *Elphidium* aff. *hughesi*, *Suggrunda* sp., *Virgulina subplana*, and *Virgulinella pertusa*. This fauna from the lower and

[17] S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), pp. 236–38, Fig. 95.

Since this account was written the Monterey shale has been penetrated in the Doheny-Bell field and has been found to be productive. The Doheny-Bell field and Las Flores field are probably areas of one field on the basis of Monterey production.

middle parts of the Sisquoc indicates correlation with the Reef Ridge shale of the San Joaquin Valley. It represents the *Bolivina obliqua* zone, which was placed by Kleinpell in the lower part of his Delmontian stage. Assignment of that zone to the upper part of the Delmontian appears to be preferable in view of the intermediate faunal division between the *Bolivina hughesi* and *Bolivina obliqua* zones mentioned in the discussion of Monterey Foraminifera. In the Santa Maria district the intermediate faunal division is represented locally in the uppermost part of the Monterey, and at a locality 2½ miles west of Casmalia was found in strata mapped with the Todos Santos claystone member of the Sisquoc. The foraminiferal faunas from the Sisquoc and Monterey indicate a discontinuity between these formations in much of the Santa Maria district, a discontinuity representing most or all of the intermediate faunal division. The fauna from the lower and middle parts of the basin facies of the Sisquoc has a definite Miocene aspect. Additional work may indicate, however, correlation with strata classed as Pliocene on the basis of larger invertebrate and vertebrate fossils.

Foraminifera from the upper few hundred feet of the basin facies of the Sisquoc are similar to those in the basal part of the overlying Foxen mudstone. They include: *Bolivina* aff. *obliqua*, relatively few specimens representing nearly typical forms of that species, *Bolivina rankini*, *Buliminella curta*, *Virgulina californiensis* var., and less numerous forms, such as *Buliminella elegantissima*, and *Uvigerina "foxeni."* This fauna is too meager and too restricted geographically to afford much basis for correlation. The stratigraphic relations suggest it is lower or middle Pliocene.

According to material collected between Foxen Canyon and Sisquoc River, the Tinaquaic sandstone member contains a neritic diatom flora characterized by *Coscinodiscus* aff. *excentricus*, *C. obscurus*, *Actinocyclus octonarius*, *Aulacodiscus sturti*, *Lithodesmium minusculum*, *Rhaphoneis angularis*, and *Fragilaria ischaboensis*. Pelagic species are rare. *Rhaphoneis angularis* occurs in the San Joaquin and Etchegoin formations of the San Joaquin Valley.[18]

A diatom flora of 228 species and varieties has been identified in samples collected from the basin facies of the Sisquoc along the Lompoc road in the western Purisima Hills. The dominant and characteristic species are: *Melosira clavigera*, *M. recedens*, *Stephanopyxis turris* var. *cylindrus*, *Endictya robusta*, *E. tubiformis*, *Coscinodiscus aeginensis*, *C. asteromphalus*, *C.* aff. *excentricus*, *C. intersectus*, *C. obscurus*, *C. stellaris*, *C. vetustissimus*, *Actinocyclus octonarius*, *Actinoptychus marmoreus*, *A. perisetosus*, *Lithodesmium cornigerum*, *Xanthiopyxis ovalis*, *Thalassionema nitzschioides*, and several undescribed forms. Pelagic species make up a third to a half of the diatoms examined. *Lithodesmium cornigerum* is the most distinctive species. It is a three-pronged diatom much like a three-bladed airplane propeller in outline and is not likely to be confused with any other diatom. It is common in the lower three-quarters of the sampled basin facies of

[18] K. E. Lohman, "Pliocene Diatoms from the Kettleman Hills, California," *U. S. Geol. Survey Prof. Paper 189* (1938), p. 92, Pl. 22, Figs. 6–8.

the Sisquoc, occurs in the silty diatomaceous strata overlying the Tinaquaic sandstone member near Sisquoc River, but was not found in other formations. This diatom is recorded from strata in the San Joaquin Valley assigned to the Etchegoin[19] and is represented by fragments from the lower part of the Etchegoin in the Kettleman Hills.[20] *Hemidiscus ovalis* and *Rhaphoneis fatula*, two species from the San Joaquin formation of the Kettleman Hills,[21] were found in the silty diatomaceous strata near Sisquoc River.

Megafossils, generally in the form of molds, are abundant in the upper half of the Tinaquaic member in the thick section east of Foxen Canyon and in the thin section on the southwest side of Foxen Canyon, which represents evidently only the uppermost part of the member. The most abundant species—*Anadara trilineata*, *Volsella* cf. *flabellata*, *Macoma* cf. *nasuta*, *Schizothaerus* cf. *nuttallii*, "*Venerupis*" cf. *hannibali*, "*Venerupis*" cf. *tenerrima*, *Cryptomya* cf. *californica*, and *Siliqua* cf. *lucida*—range upward into younger formations. *Dendraster* cf. *coalingaensis*, "*Nassa*" sp., and *Patinopecten lohri* are the most distinctive species. The thin moderately eccentric sand dollar identified as *Dendraster* cf. *coalingaensis* was found in coarse-grained sandstone near the top of the member on both flanks of the syncline near Sisquoc River and on the southwest side of Foxen Canyon.

Patinopecten lohri indicates lower or middle Pliocene in terms of the San Joaquin Valley section. Inasmuch as the characteristic genera of the lower Pliocene of the San Joaquin Valley and other districts have not been found in the fossiliferous part of the Tinaquaic in the mapped area, that part is considered of middle Pliocene age and is correlated with the Etchegoin formation. *Pseudocardium* cf. *densatum*, which is rare in the Tinaquaic, also indicates lower or middle Pliocene. It is, however, widespread in the Graciosa coarse-grained member of the Careaga sandstone. L. M. Clark[22] recorded lower Pliocene fossils, characteristic of the Jacalitos formation, from the lower part of the Pliocene section in the Santa Maria Basin. Perhaps the lower half of the thick Tinaquaic section east of Foxen Canyon, in which no megafossils were found, is lower Pliocene. According to a communication from Clark, his lower Pliocene localities are east of the mapped area. Calcareous coarse-grained sandstone on the south side of Sisquoc River, 0.8 mile east-northeast of the mouth of Round Corral Canyon and $2\frac{1}{4}$ miles beyond the east border of the mapped area, contains *Astrodapsis* cf. *arnoldi* and *Lyropecten* cf. "*terminus*." This fossiliferous sandstone represents presumably part of the Tinaquaic member and is correlated with the lower Pliocene Jacalitos formation of the San Joaquin Valley. Neither genus is known to occur in the Tinaquaic of the mapped area.

[19] G. D. Hanna, "Observations on *Lithodesmium cornigerum* Brun," *Jour. Paleon.*, Vol. 4 (1930), p. 190, Pl. 14, Figs. 9, 10.

[20] K. E. Lohman, *op. cit.* (1938), p. 85.

[21] K. E. Lohman, *op. cit.* (1938), p. 91, Pl. 22, Fig. 9; p. 93, Pl. 22, Fig. 5.

[22] L. M. Clark, in R. D. Reed, *Geology of California*, Amer. Assoc. Petrol. Geol. (1933), p. 232.

Mollusks are found virtually throughout the diatomaceous strata of the Sisquoc formation. They are represented by molds with the exception of a few localities where shells are preserved in oil-impregnated diatomaceous mudstone, notably at the N.T.U. mine in the western Casmalia Hills and at several localities on Graciosa Ridge in the Orcutt field, including the dump of the long abandoned Pennsylvania asphalt mine near Rice Ranch well No. 15 and a locality near Newlove well No. 37, all of which represent strata near the top of the formation. *Bittium casmaliense*, *Crepidula princeps*, *Calyptraea* cf. *fastigiata*, *"Nassa" waldorfensis*, *Mitrella gausapata*, *Saccella orcutti*, *Anadara trilineata*, *Katherinella* (*Compsomyax*) cf. *subdiaphana*, and *Psephidia* sp., the most abundant species, are found also in younger formations in the Santa Maria district. *Nuculana* sp., *Ostrea* sp., and *Pandora* cf. *filosa* are the only species so far examined that are not known to range higher. The *Nuculana* may be regarded as the most characteristic megafossil of the diatomaceous strata of the Sisquoc. It was collected in every area where diatomaceous strata of the Sisquoc crop out and is found at the top of the Sisquoc in the subsurface section of the Las Flores field, but was not recognized in the few cores from the Santa Maria Valley field that were examined. In the Purisima Hills it ranges virtually throughout the formation, but as in other areas is most abundant near the top. *Patinopecten dilleri* and a variety of that species characterized by minor riblets were collected at the N.T.U. mine. Incomplete shells from that locality are identified as *Patinopecten lohri?* and incomplete molds from a locality near Redrock Mountain in the Purisima Hills as *Patinopecten* cf. *lohri*.

The split-rib *Patinopecten* cf. *lohri* is the only mollusk of distinctly Pliocene affinities from the lower part of the diatomaceous facies of the Sisquoc, the most abundant species being *Crepidula princeps*, *Calyptraea* cf. *fastigiata*, and *Anadara trilineata*[22a]. Split-rib Patinopectens are unrecorded in the California Miocene. The occurrence of a split-rib *Patinopecten* at the locality near Redrock Mountain led Arnold and Anderson[23] to conclude that Pliocene diatomaceous strata are represented at that locality. As a matter of fact the fossiliferous strata near Redrock Mountain are in the lower part of the Sisquoc formation. In view of the Miocene affinities of Foraminifera from the lower part of the diatomaceous strata of the Sisquoc that part of the formation is considered upper Miocene (?), and the entire formation is thought to range from upper Miocene (?) to middle Pliocene. The upper part of the formation at the N.T.U. mine contains many mollusks of upper Pliocene affinities, but contains also *Patinopecten lohri?*.

Megafossils from the Tinaquaic member represent a shallow-water facies; those of the basin facies represent a moderate-depth facies but include many species related to forms that range into shallow water.

[22a] In a recent publication Reinhart questions Miocene records of *Anadara trilineata*. (P. W. Reinhart, "Mesozoic and Cenozoic Arcidae from the Pacific Slope of North America," *Geol. Soc. America Spec. Paper* 47 (1943), p. 58.

[23] Ralph Arnold and Robert Anderson, *op. cit.* (1907), pp. 54–55.

FOXEN MUDSTONE

According to current usage, the type region of the Foxen mudstone is on the north slope of the western Purisima Hills, where it is 800 feet thick, the maximum outcrop thickness in the district. The Foxen consists chiefly of mudstone and siltstone, but includes fine-grained silty sandstone and fine-grained volcanic ash. It is not represented at the eastern margin of the basin and on anticlines in the basin (Figs. 2, 4). In complete sections, such as that in the type region (Fig. 3, A),

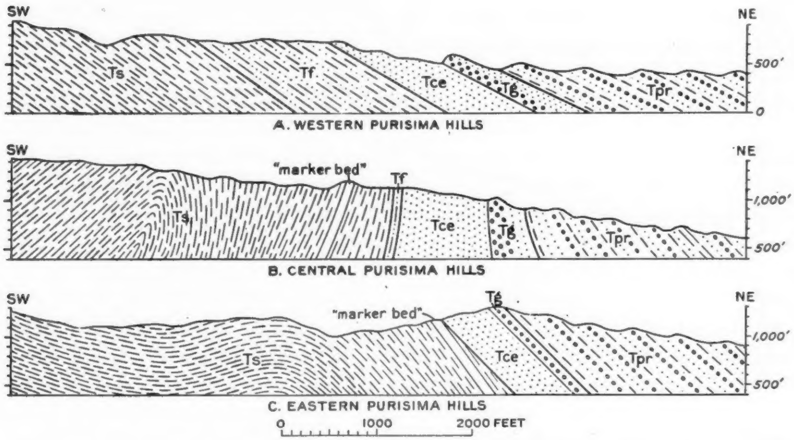


FIG. 3.—Stratigraphic relations of Foxen mudstone and Careaga sandstone in Purisima Hills.
Tpr, Paso Robles formation.
Tg, Graciosa coarse-grained member of Careaga sandstone.
Tce, Cebada fine-grained member of Careaga sandstone.
Tf, Foxen mudstone.
Ts, Diatomaceous strata of Sisquoc formation.

the Foxen overlies gradationally diatomaceous strata of the Sisquoc formation and grades upward into the Cebada fine-grained member of the Careaga sandstone. In the Casmalia Hills conglomerate and calcareous strata are rare constituents of the Foxen. Conglomerate in the western Casmalia Hills contains boulders and slabs of contorted chert 3 to 6 feet long, indicating that somewhere near by the Foxen, as well as the upper part of the Sisquoc, overlapped onto the Monterey.

In most of the areas where the Foxen is missing as a lithologic unit it is probably represented by a condensed section of fine-grained sandstone mapped with the overlying Cebada fine-grained member of the Careaga sandstone and grading upward from diatomaceous strata of the Sisquoc formation. The present anticlines were evidently ridges on the floor of the Foxen sea and the finest sediments were winnowed out on the crest of the ridges and swept into the adjoining syn-

clinal basins. Updip on the north flank of the western Purisima Hills the Foxen is progressively more sandy and contains more phosphatic pellets. Eastward in the Purisima Hills the Foxen grades into fine-grained sandstone mapped with the Cebada sandstone (Fig. 3, B). As the Foxen thins and disappears beds made up chiefly of phosphatic pellets are more numerous both in the basal part of the Cebada and at the top of the Sisquoc. The beds composed largely of phosphatic pellets appear to represent a greatly condensed deposit corresponding with the uppermost Sisquoc and the Foxen of more complete sections on the west.

In subsurface sections geologists draw the base of the Foxen at the base of a tar sand[24] that is readily recognized on electric logs. The occurrence of Foraminifera like those in the upper part of the Sisquoc of outcrop sections, the occurrence of the Sisquoc *Nuculana*, and the type of lithology in cores from Las Flores well No. 1 indicate that in the Las Flores field the tar sand is about 1,000 feet lower than the base of the Foxen as mapped in outcrop sections. Though the tar sand is a convenient datum plane for subdividing subsurface sections, it should be borne in mind that, if it is used as the base of the Foxen, the subdivision of the subsurface section in the Las Flores field and presumably in other areas does not agree with the subdivision of the outcrop section adopted in the present report.

Foraminifera are abundant in the Foxen mudstone, but include relatively few species, and some of them are provincial forms not yet known elsewhere. As pointed out by Canfield,[25] they suggest decreasing depth facies upward in the formation. The similarity of the faunas from the uppermost part of the Sisquoc and the basal part of the Foxen has already been mentioned. The form listed as *Bolivina* aff. *obliqua* and the variety of *Virgulina californiensis* occur in both. Somewhat higher strata in the lower part of the Foxen are characterized by *Bolivina* aff. *tumida*, a great abundance of *Uvigerina "foxeni,"* and the progressively common occurrence of Buliminas. The Buliminas are variable and include forms resembling *B. pulchella* and *B. deformata*. Higher in the Foxen they tend to develop toward the *B. denudata* type. Increasingly sandy strata in the upper part of the Foxen contain species of more shallow-water facies—species of *Elphidium*, *Elphidiella*, and *Nonion*.

Foxen Foraminifera are too restricted geographically to afford a satisfactory basis for correlation. The more shallow-water forms in the upper part of the formation are associated with upper Pliocene megafossils and offer no conflict with such an age assignment. The Foraminifera in the lower part of the formation may be of middle Pliocene age. That suggestion is based, however, on comparison with the upper Sisquoc fauna and on stratigraphic considerations rather than on faunal similarities with middle Pliocene strata elsewhere.

The Foxen mudstone along the Lompoc road in the western Purisima Hills

[24] C. R. Canfield, *op. cit.* (1939), p. 58. S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), pp. 235–36.

[25] C. R. Canfield, *op. cit.* (1939), pp. 59–60.

has yielded a diatom flora of 242 species and varieties. Abundant and characteristic species are: *Melosira sulcata*, *Podosira montagnei*, *Stephanopyxis turris* and var. *cylindrus*, *Endictya robusta*, *Coscinodiscus asteromphalus*, *C. cirrus*, *C. excentricus*, *Xanthiopyxis ovalis*, *Thalassiothrix longissima*, and *Navicula pennata*. The Foxen flora is similar to that from the San Joaquin formation, the principal difference being the much larger number of pelagic diatoms in the Foxen. *Coscinodiscus cirrus* is a San Joaquin species.[26]

Megafossils are common in the upper part of the Foxen mudstone in the Casmalia Hills, but are absent generally in the Purisima Hills. *Bittium casmaliense*, *B. casmaliense arnoldi*, *Crepidula princeps*, "*Nassa*" *waldorfensis*. *Mitrella gausapata*, and *Saccella orcutti*, the most abundant Foxen species, are found in both older and younger formations. *Dendraster* (*Merriamaster*) cf. *perrini* occurs in the Foxen and is the only *Merriamaster* from the Santa Maria district. *Patinopecten dilleri* is common in the Foxen, but is represented in the upper part of the Sisquoc formation at the N.T.U. mine and was collected at one locality from the Cebada fine-grained member of the Careaga sandstone. If Arnold and Anderson's collection and later collections from the dump of the old Waldorf asphalt mine[27] represent the Foxen mudstone, as appears probable, "*Gyrineum*" cf. *elsemerensis*, *Neptunea* cf. *stantoni*, and *Thyasira* cf. *gouldii* are Foxen species that are not known to occur in other formations in the district.

Most of the Foxen megafossils represent a moderate-depth facies. In the Casmalia Hills, however, the formation includes both moderate-depth and shallow-water facies.

Megafossils from the upper part of the Foxen indicate upper Pliocene, the equivalent of the San Joaquin formation in the San Joaquin Valley and of the upper part of the San Diego formation, the part exposed at Pacific Beach near San Diego. *Merriamaster*, *Opalia varicostata*, "*Cancellaria*" *arnoldi*, and *Patinopecten healeyi*, all of which occur in the Foxen, suggest strongly the upper part of the San Diego formation. *Merriamaster* is associated with a fauna like that in the upper part of the San Diego formation at localities from Cedros Island, Lower California, northward to the Santa Maria and Coalinga districts.

CAREAGA SANDSTONE, INCLUDING CEBADA FINE-GRAINED MEMBER AND GRACIOSA COARSE-GRAINED MEMBER

The name for the next younger formation, the Careaga formation[28]—altered in the present report to Careaga sandstone—was chosen in 1938 at a conference of geologists interested in the Santa Maria district. The type region is on the north flank of the Purisima Hills south of Careaga station on the now abandoned Pacific Coast Railroad, where the formation is 725 feet thick and overlies grada-

[26] K. E. Lohman, *op. cit.* (1938), p. 90, Pl. 21, Fig. 4.

[27] Ralph Arnold and Robert Anderson, *op. cit.* (1907), p. 60 (locality 4473).

[28] S. G. Wissler and F. E. Dreyer, *op. cit.* (1941), p. 235.

tionally the Foxen mudstone. Throughout most of the district the Careaga is subdivided into two mapped members not shown in Figure 1: a lower fine-grained sandstone unit designated the Cebada fine-grained member, and an upper coarse-grained sandstone and conglomerate unit, the Graciosa coarse-grained member. The type region of both members is the same as the type region of the formation.

The thickness of the Careaga ranges from 50 to 1,425 feet. The greatest range is in the Cebada member, which is absent at places and has a maximum thickness of 1,000 feet. The thickness of the Graciosa member is 25 to 425 feet. The thickest sections are in synclines, the most abbreviated sections are on anticlines and at the eastern margin of the basin, indicating that the synclines and anticlines were basins and ridges, respectively, during Careaga time. The stratigraphic relations of the Careaga sandstone show a close correlation with structural features. Along

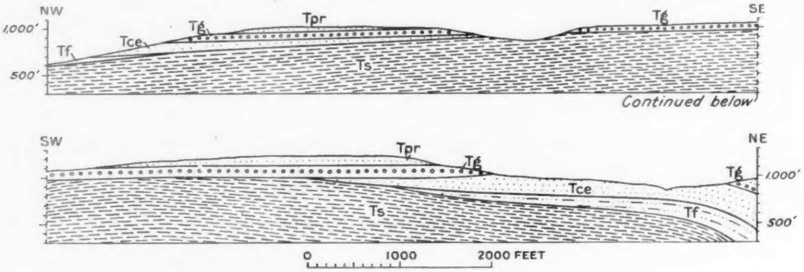


FIG. 4.—Stratigraphic relations of Careaga sandstone on Graciosa Ridge.
Tpr, Paso Robles formation.
Tg, Graciosa coarse-grained member of Careaga sandstone.
Tce, Cebada fine-grained member of Careaga sandstone.
Tf, Foxen mudstone.
Ts, Diatomaceous strata of Sisquoc formation.

Foxen Canyon adjoining the eastern margin of the basin either the Cebada member or the Graciosa member overlies the Monterey with marked discordance (Fig. 2, A, B). Eastward on the north flank of the eastern Purisima Hills the Cebada member overlaps part of the Sisquoc formation, the overlap being shown by relations to the "marker bed" near the top of the Sisquoc (Fig. 3, C). In the interior of the eastern Purisima Hills undifferentiated sandstone of the Careaga overlies discordantly the lower part of the Sisquoc or the upper member of the Monterey. On Graciosa Ridge in the Orcutt field the Graciosa member overlaps the Cebada member and rests on the Sisquoc formation (Fig. 4).

The Cebada fine-grained member consists of fine-grained, generally massive, soft sandstone. The lower part is typically very fine-grained and light gray, but most of the sandstone is light yellowish brown. The Graciosa coarse-grained member is made up of two parts: a lower part consisting of coarse-grained soft sandstone and conglomerate, and an upper part consisting of coarse-grained soft

sandstone. Pebbles of porcelaneous shale derived from the Monterey are abundant in most of the beds of conglomerate. Where the Careaga is typically developed the upper part of the Graciosa member forms a belt of deep sandy soil between conglomerate in the lower part of the member and clay at the base of the Paso Robles formation. Except in the seaward part of the basin the upper part of the Graciosa member is probably non-marine.

A meager fauna of shallow-water Foraminifera is found locally in the Cebada member, the most common species being *Elphidiella hannai.*

Megafaunal differentiation of the Cebada and Graciosa members of the Careaga sandstone is an expression of difference in faunal facies, as, indeed, are most other Pliocene megafaunal characteristics in the Santa Maria district, the only faunas of comparable facies being those from the Tinaquaic member of the Sisquoc and the Graciosa coarse-grained member of the Careaga. The Cebada member represents a moderate-depth facies, the Graciosa a shallow facies. The Cebada megafauna is exceptionally large, owing to the large number of species found at two localities where sandstone is impregnated with tar: Fugler Point, located in the bluffs on the south border of Santa Maria River, and a locality on the south slope of Graciosa Ridge in the Orcutt field near Newlove well No. 42, at both of which almost 100 species representing the same faunal association were collected. These exceptional localities yielded about 50 species not found elsewhere in the Cebada member or in other units, notably *Terebratalia* cf. *occidentalis, Turritella gonostoma hemphilli, Crepidula aculeata, Crucibulum* cf. *imbricatum, Trivia* cf. *sanguinea, Erato* cf. *scabriuscula, Architectonica* sp., *Calicantharus portolaensis, Crawfordina fugleri, Glyphostoma conradiana, Acila castrensis, Barbatia pseudoillata,* and *Chlamys etchegoini parmeleei.* If the collections from the Waldorf mine are from the Foxen mudstone, the Foxen at that locality has a faunal association resembling the association at the two Cebada localities mentioned. *Dendrophyllia* sp., *Puncturella cucullata, Turcica imperialis brevis, "Gyrineum" mediocre lewisii, Fusitriton* cf. *oregonensis, Jaton* cf. *carpenteri, Psephaea oregonensis, Propebela* sp., *Arca sisquocensis,* and *Arca santamariensis* are in Arnold and Anderson's collection from the Waldorf mine and in one or both Cebada collections but not in others.

Aside from the Cebada localities just discussed, the Cebada and Graciosa megafaunas may be recognized principally by differences in relative abundance of species. *Glottidia* is rare in the Cebada and is not known to occur in the Graciosa; a small variety of *Trochita radians* occurs in the Cebada and Foxen but not in the Graciosa; a relatively enormous *Platyodon?* was found only in the Graciosa. The thin very eccentric sand dollar *Dendraster ashleyi* is abundant and widespread in the Graciosa and is present at one locality mapped as Cebada. *Yoldia* cf. *cooperi, Patinopecten healeyi, Lyropecten cerrosensis,* and *Lucinoma* cf. *annulata* are more abundant in the Cebada, whereas *"Nassa" moraniana, "Cancellaria" rapa perrini,* a slender variety of *Olivella biplicata, "Drillia" graciosana, Macoma* cf. *nasuta, Pseudocardium* cf. *densatum, "Venerupis"* cf. *hannibali,* and

Pandora cf. *punctata* are more abundant in the Graciosa. *Strioterebrum martini* is rare in both units.

The Careaga sandstone, as well as the upper part of the Foxen, is assigned to the upper Pliocene and is correlated with the San Joaquin formation and the upper part of the San Diego formation. *Turritella gonostoma hemphilli*, *Opalia varicostata*, *O. varicostata anomala*, "*Cancellaria*" *arnoldi*, *Chlamys etchegoini parmeleei*, *Patinopecten healeyi*, and *Lyropecten cerrosensis* show a close relationship to the upper part of the San Diego formation. A form of *Calliostoma coalingense*, *Turcica imperialis brevis*, "*Nassa*" *waldorfensis*, "*Cancellaria*" *rapa*, *Acila castrensis*, and *Patinopecten healeyi* suggest the San Joaquin formation.

A close agreement with the succession of Pliocene faunas in the San Joaquin Valley is not apparent and is perhaps not to be expected. "*Nassa*" *moraniana*, *Calicantharus portolaensis*, *Lyropecten*, *Pseudocardium*, and *Dosinia* are characteristic of the Jacalitos and Etchegoin formations (lower and middle Pliocene, respectively) of the San Joaquin Valley. In the Santa Maria district, however, they are most abundant in, or are found only in, strata assigned to the upper Pliocene. The stratigraphic position of sand dollars characterized by different degrees of eccentricity is reversed in the two districts. In the San Joaquin Valley the very eccentric *Dendraster gibbsii* is characteristic of the Jacalitos and Etchegoin; the moderately eccentric *D. coalingaensis* is characteristic of the San Joaquin formation.[29] The ranges are not narrowly restricted, as a small variety of *D. gibbsii* occurs in the lower part of the San Joaquin and a variety of *D. coalingaensis* in the upper part of the Etchegoin. In the Santa Maria district the moderately eccentric *D.* cf. *coalingaensis* characterizes the Tinaquaic sandstone member of the Sisquoc, and the very eccentric *D. ashleyi* the Careaga sandstone. Despite the marked eccentricity, the thin test of *D. ashleyi* suggests closer relationship to *D. coalingaensis* than to *D. gibbsii*. Perhaps the most satisfactory basis for megafossil age assignments in the Santa Maria district is furnished by the occurrence of *Patinopecten lohri* in the Sisquoc formation, *Patinopecten healeyi* in the Foxen and Careaga, and *Merriamaster* in the Foxen.

As may be expected from the location of the Santa Maria district, the megafaunas have northern and southern affinities. "*Gyrineum*" *mediocre lewisii*, *Fusitriton* cf. *oregonensis*, *Neptunea* cf. *stantoni*, *Psephaea oregonensis*, and *Pseudocardium* have northern affinities and are presumably migrants from the north. *Merriamaster*, *Turritella gonostoma hemphilli*, *Crepidula aculeata*, *Trochita radians*, *Crucibulum* cf. *imbricatum*, *Trivia* cf. *sanguinea*, *Erato* cf. *scabriuscula*, *Architectonica*, "*Cancellaria*" *arnoldi*, *Strioterebrum martini*, and *Lyropecten cerrosensis* are southern forms or have been found in Pliocene deposits only farther south.

PASO ROBLES FORMATION

The nonmarine Paso Robles formation overlies conformably the Careaga sandstone and has an exposed maximum thickness of about 2,000 feet. Sandstone

[29] Ralph Stewart, in W. P. Woodring, Ralph Stewart, and R. W. Richards, "Geology of the Kettleman Hills Oil Field, California," *U. S. Geol. Survey Prof. Paper 195* (1940 (1941)), pp. 79–83.

and conglomerate—or sand and gravel, for most of the material is quite unconsolidated—are the principal lithologic types in the Paso Robles. Clay and limestone are minor but the most characteristic constituents. The discontinuous beds of clay, accompanied generally by limestone, marking the base of the Paso Robles, represent evidently a zone 50 to 100 feet thick recognized almost throughout the district. In the few areas where clay or limestone were not found at an expectable horizon above the Careaga sandstone the base of the Paso Robles is uncertain. The gravel and conglomerate of the Paso Robles are made up chiefly of porcelaneous shale pebbles. Cobbles of brown sandstone characterized by abundance of mica—sandstone derived evidently from the extensive outcrops of Cretaceous strata in the San Rafael Range—occur in conglomerate of the Paso Robles in the northern part of the district and are in general more common than in conglomerate of the Careaga sandstone. In the western Casmalia Hills and in subsurface sections of adjoining parts of the Santa Maria Valley the basal part of the Paso Robles includes thin tongues of marine strata.

Clay and limestone in the Paso Robles formation contain fresh-water ostracodes and fresh-water mollusks of the genera *Amnicola*, *Lymnaea*, *Menetus*, *Gyraulus*, *Physa*, and *Sphaerium*, not yet identified. This fresh-water fauna is too small to compare satisfactorily with that at the base of the Tulare formation of the Coalinga district. The few marine fossils found near the base of the Paso Robles in the western Casmalia Hills are not diagnostic. The Paso Robles formation of the Santa Maria district is assigned tentatively to the upper Pliocene and lower Pleistocene (?). Professor Stock reports that remains of a ground sloth of Pleistocene type have been found near Edna, 15 miles north of Santa Maria River, presumably in the Paso Robles formation.

ORCUTT SAND

Sand and gravel resting discordantly on the Paso Robles and older formations are designated the Orcutt sand. The type region is on the north flank of the Casmalia Hills west of Orcutt. In that region the Orcutt sand has a maximum thickness of about 50 feet and overlaps unconformably formations down to and including the Sisquoc. Throughout the district the maximum thickness is between 50 and 100 feet. Silt and clay are local rare constituents of the Orcutt sand. The Orcutt sand may be regarded as the oldest and most extensive terrace deposit in the Santa Maria district. It is tilted as much as 12° on the flanks of anticlines, indicating late uplift of those folds.

At localities where the Orcutt overlies gently dipping Paso Robles identification of the two formations may be difficult. Sand in the Orcutt, and also in younger terrace deposits, is reddish brown owing to a ferruginous coat on the sand grains, and is characteristically rilled and fluted on steep slopes. Gravel in the Orcutt contains pebbles of local rocks not recognized in the Paso Robles formation, such as diatomaceous mudstone and reddish burnt shale, both derived from the Sisquoc formation.

The Orcutt sand is thought to be upper Pleistocene. Ostracodes and *Amni-*

cola?, found in clay in the Orcutt in the Purisima Hills, are apparently of no value in age determination.

TERRACE DEPOSITS YOUNGER THAN ORCUTT SAND

Gravel and sand representing stream terrace deposits younger than the Orcutt sand were differentiated principally on a basis of physiographic development. For the most part they were not mapped carefully and at places may include the equivalent of the Orcutt sand. The stream terrace deposits are generally not more than 25 feet thick. Along the Sisquoc River east of Foxen Canyon the thickness is estimated to be as much as 75 feet. Unlike the Orcutt sand, these terrace deposits are not deformed, with the exception that near Sisquoc River between Cat Canyon and Foxen Canyon they appear to be arched in a low, ill-defined anticline.

Five marine terraces are recognized along the coast, the platform of the highest of which is at an altitude of about 850 feet. Correlation of terraces from place to place in the western Casmalia Hills is, however, uncertain. Marine deposits, consisting of sand, calcareous sand, and gravel, locally cemented, are found at places immediately above the platform of three terraces, including the highest and the lowest. The marine deposits are a foot to 6 feet thick. Nonmarine sand, gravel, and rubble, constituting the nonmarine terrace cover, overlie the marine deposits or in their absence rest directly on the terrace platform. The nonmarine cover has a maximum thickness of about 100 feet. The sand is rilled and fluted on steep slopes and much of it is reddish brown.

The marine deposits on the marine terraces contain species living along the coast in the latitude of the Santa Maria district. They are presumably of late Pleistocene age.

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EOCENE STRATIGRAPHY OF CHICO MARTINEZ CREEK AREA, KERN COUNTY, CALIFORNIA[1]

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ABSTRACT

Although the geology of the Chico Martinez Creek area has been studied several times since 1905, the Oligo-Miocene beds have received the most attention, and the Eocene strata have been virtually ignored. The purpose of the present study is to record the detailed stratigraphy and paleontology of these Eocene strata immediately subjacent to the Zemorrian stage at its type locality. Three faults and two folds of importance are mapped. Ecologic analyses of the foraminiferal assemblages of Zemorra Creek suggest that the "Tejon" formation was deposited in the open sea at or below the edge of the continental shelf and at a latitude where surface waters were tropical or sub-tropical. Rapid accumulation of detritus on a steeply sloping bottom profile is also indicated. Comparison of check lists of Foraminifera shows that members 1, 2, and the upper part of member 3 of the "Tejon" formation of Zemorra Creek are probably equivalent in age to the Sagasar shale member of the Kreyenhagen formation of Reef Ridge and that the lower part of member 3 and members 4, 5, 6, and 7 are probably equivalent to the Canoas siltstone member. Thus, while siliceous shales were being deposited in the Reef Ridge district, coarse sandstones were being deposited in the Chico Martinez Creek–Carneros Creek region. Attempted correlation with the type Tejon formation and the type Devil's Den shale was unsuccessful.

INTRODUCTION

Location of area.—The area investigated is in the Temblor Range, western Kern County, California, about 20 miles northwest of the town of McKittrick; it includes parts of Secs. 4, 5, 6, 9, and 10, T. 29 S., R. 20 E., and of Secs. 35 and 36, T. 28 S., R. 20 E., M. D. B. & M. Figure 2 is a geologic map of a roughly rectangular district about 2½ miles long and 1½ miles wide. Carneros Creek is the northern limit and Zemorra Creek the southern. About 8 miles due east of the area is the Belridge oil field. The North Belridge oil field is about 10 miles northeast. The district may be reached by graded dirt roads from California State Highway No. 33.

Purpose and scope.—The purpose of this study is to record the stratigraphy and paleontology of the strata immediately subjacent to the Zemorrian stage (Kleinpell, 1938) at its type locality, thereby presenting a strategically situated Eocene section approximately midway between the type localities of the Kreyenhagen and Tejon formations.

The field work for the study was carried on during September and October, 1941, measurement of the Zemorra Creek section in March, 1942, and final work in September, 1942. The field base map was made from the United States Department of Agriculture aerial photographs to the scale of 1,666 feet to the inch. Figure 2 is based on tracings from these photographs. The detail map of Zemorra Creek (Fig. 5) is made from a tracing of a plane-table traverse to the scale of 500

[1] Manuscript received, April 2, 1943. A thesis submitted to the department of Geology and the committee on graduate study of the Leland Stanford Junior University in partial fulfillment of the requirements for the degree of Master of Arts, 1942.

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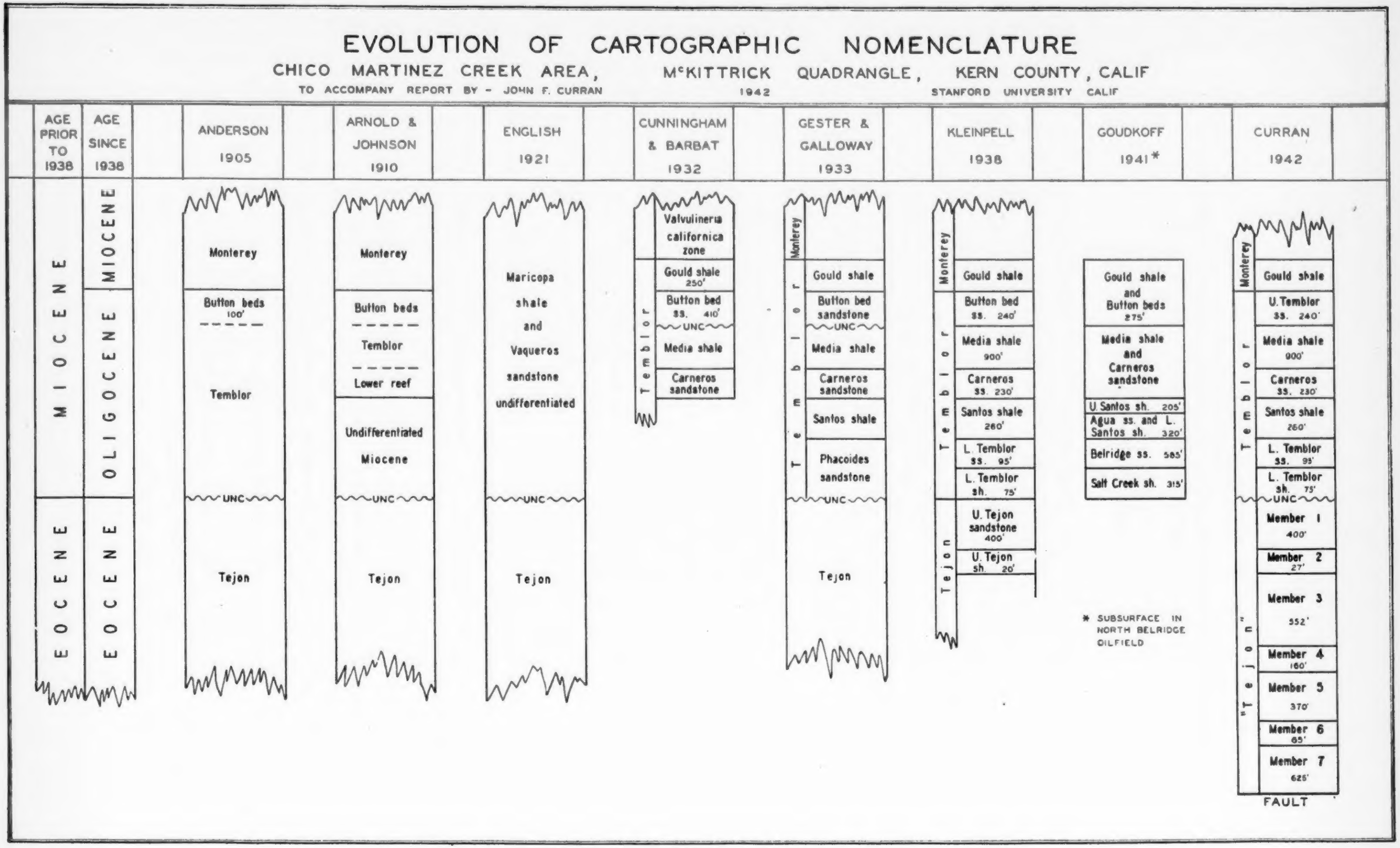


Fig. 1.—Evolution of cartographic nomenclature.

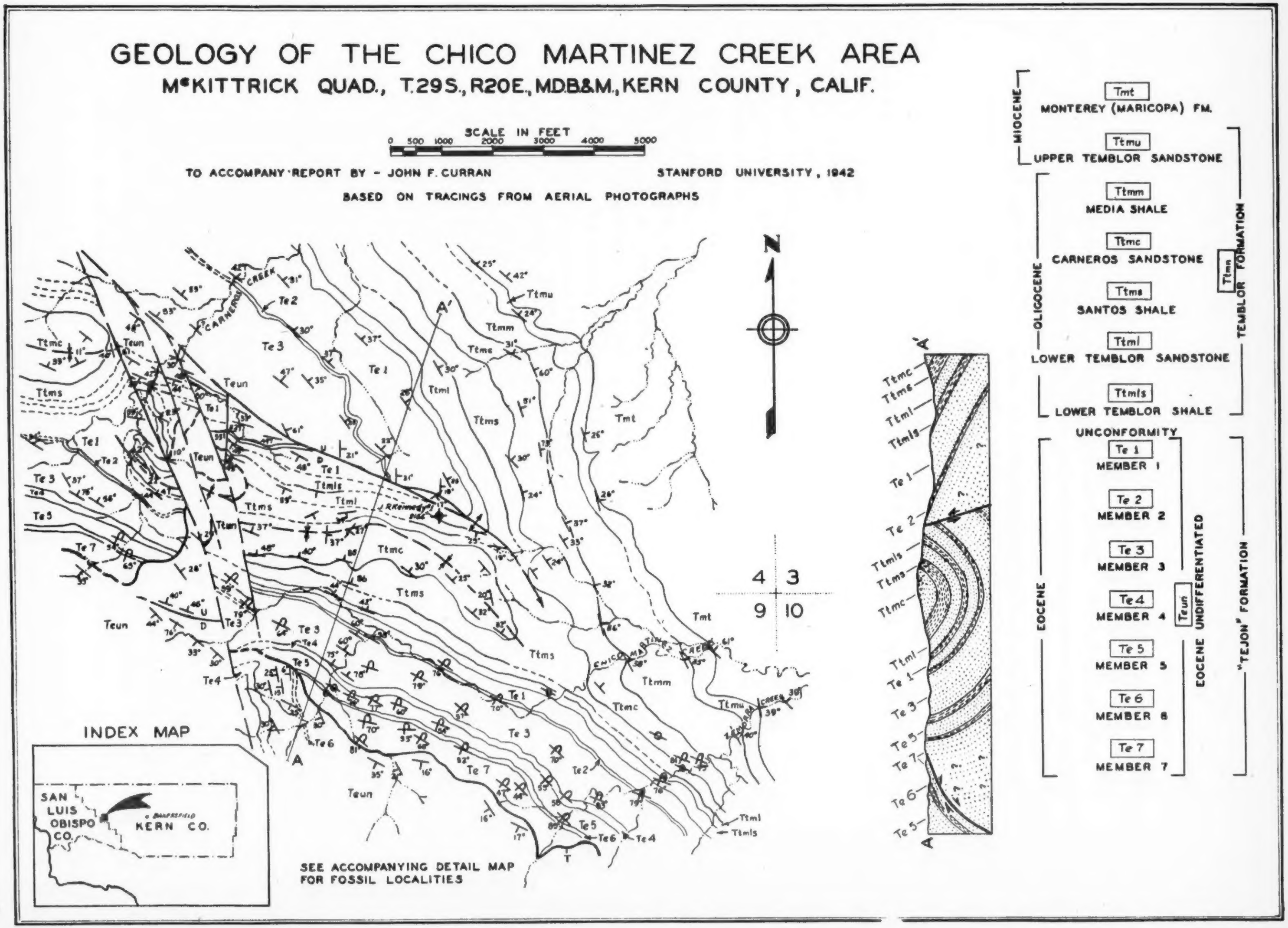


FIG. 2.—Geologic map of Chico Martinez Creek area.

feet to the inch. With the exception of this traverse, all elevations necessary for topographic control were obtained by altimeter traverse.

Topographic features.—The principal topographic features of the area are the abrupt change in topography from the rounded hills and gentle slopes in the northeastern section to the steep slopes and sharp ridges along the upper part of Zemorra and Chico Martinez Creeks, and the series of bold outcrops formed by the Eocene sandstones near Carneros Creek. These outcrops, known locally as the "Carneros Rocks," form prominent ridges, dip slopes, and cliffs in places 100 feet high.

ACKNOWLEDGMENTS

This work was supervised by H. G. Schenck of Stanford University. Financial assistance was received from the Honolulu Oil Corporation through the cooperation of Elmo W. Adams, chief geologist. Paul McGovney of the same corporation assisted in the surveying of the Zemorra Creek section. The preparation of foraminiferal samples in the laboratory was made possible through the courtesy of Hampton Smith and J. M. Hamill, The Texas Company, with the helpful collaboration of their laboratory staff. The faculty of the Division of Geological Sciences of the California Institute of Technology placed library and laboratory facilities at the writer's disposal. Lois T. Martin identified most of the microfossils here recorded. Robert T. White, Barnsdall Oil Company, William F. Barbat, Standard Oil Company, A. R. May, Superior Oil Corporation, Lesh Forrest and R. Stanley Beck, Richfield Oil Corporation, and D. D. Hughes and Konrad Krauskopf, Stanford University, made timely suggestions during the progress of the work. To all of these the writer expresses his sincere thanks.

PREVIOUS WORK

No report has been published on detailed geological work in the Carneros Creek-Zemorra Creek district. Especially notable is the paucity of publications about the Eocene rocks and fossils of this area.

Early workers, for example, Gabb and Whitney, made a few generalized statements about the geology of the entire Temblor Range but contributed little of lasting value to the knowledge of this particular district. The earliest specific mention of it was by Frank M. Anderson (1905). He named the Temblor formation and designated its type locality at Carneros Spring, but he presented no adequate type description. Of the Eocene rocks he said little except passing comment on the massive outcrops at Carneros Spring.

Arnold and Johnson (1910) published the first geological map of the region but gave no detailed description of the stratigraphy of the Eocene beds. They referred to the type Temblor formation as the Vaqueros formation, thus contributing confusion to the stratigraphic nomenclature (Fig. 1). They agreed with Anderson in the recognition of an unconformity at the top of what they called the Tejon formation. English (1921) also mapped the area but devoted more attention to beds of Miocene and younger age rather than to the Eocene. He also

placed an unconformity at the top of the "Tejon" formation. Kleinpell (1938) selected Zemorra Creek as the type locality for the Zemorrian stage. He presented a detailed section from the Gould shale member of the Monterey formation down to the first shale in the "Tejon" formation, together with a systematic catalog of microfossils for this and equivalent sections. He considered the Temblor and the "Tejon" to be accordant and conformable and placed the uppermost sandstone unit of the "Tejon" in the Refugian stage.

The present writer makes no attempt at a revision of cartographic nomenclature, with the exception of the substitution of the name Upper Temblor sandstone for "Button Bed sandstone" in referring to the uppermost member of the Temblor formation. Detailed work was confined to the Eocene beds, but, since the area mapped was relatively small, lithologic units are merely numbered. Though, as shown later, these beds are not equivalent to the type Tejon formation, the name is retained and they are referred to as the "Tejon" formation.

STRATIGRAPHY

In the section of the Temblor Range between the town of McKittrick on the south and Antelope Valley on the north there is exposed a thick series of Tertiary sedimentary rocks, some Cretaceous strata, and here and there outcroppings of the Franciscan "series." The regional strike of the strata is northwest-southeast although this trend is modified locally by folding and faulting.

In the area investigated in the vicinity of Chico Martinez Creek, however, only Eocene, Oligocene, and Miocene formations are present. The Eocene strata have been referred to in published reports as the "Tejon" formation or as the "cavernous-weathering sandstone." These beds are overlain, probably unconformably, by the Temblor formation which is in turn conformably overlain by the Monterey or "Maricopa" formation. This area is the type locality for the Gould shale member of the Monterey formation, for the Oligo-Miocene Zemorrian stage, and for the Temblor formation.

In the present work, attention was directed principally to the 2,300 $\pm$ feet of sandstones and shales comprising the "Tejon" formation which are immediately subjacent to the Zemorrian stage.

"Tejon" formation (Eocene).—This "cavernous-weathering sandstone" is made up of a thick sequence of boldly outcropping sandstones and interbedded nodular, foraminiferal shales. The formation is exposed in a broad band along the southwestern border of the area mapped and also on the flanks of the Carneros anticline. The maximum exposed thickness is 2,300 feet as measured on Zemorra Creek. Since the base of the formation is not exposed in the area, the total thickness can not be determined. The formation, as exposed, can be divided into seven members, four consisting of sandstone and three consisting of shale. Each member may readily be traced for several miles. The relative thicknesses of these units as exposed on Zemorra Creek, Chico Martinez Creek, and at Carneros Spring are shown in Figure 3. The upper member is disconformably overlain by the Tem-

blor formation, and the base of the formation is delimited by the Temblor thrust fault. Each of the seven members is conformable with the adjacent members. The sandstones are distinctive in that they are strikingly different lithologically from the overlying Oligo-Miocene beds. They are essentially coarse-grained, and thin sections show a marked angularity and freshness of the grains. The composition is principally quartz with large amounts of feldspar and varying amounts of mica. Conspicuous is the general paucity of ferro-magnesian minerals. The sandstones also contain numerous large concretions (6 inches to 4 feet in diameter)

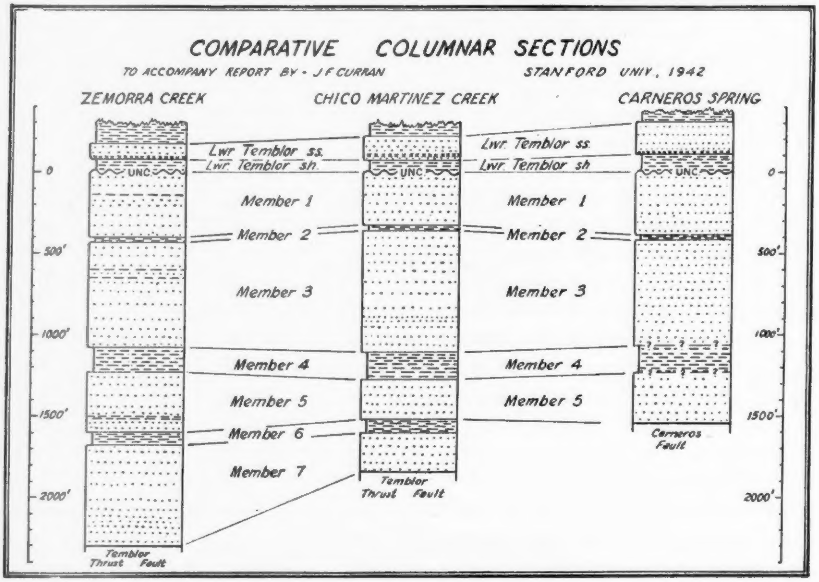


FIG. 3.—Comparative geologic columns.

which characteristically have a copper-red weathered surface. Where outcrops are poor these concretions are scattered abundantly on the surface of the ground. Large cavities in the sandstones are produced by weathering, commonly where the concretions have weathered out. Such cavities in the vicinity of Carneros Spring are 6 to 8 feet high and are decorated by old Indian mural paintings.

In Zemorra Creek the following section was studied.

Temblor formation	*Feet*
Unconformity	
"Tejon" formation	
Member 1	400
136 feet sandstone. Massive, friable, medium-grained. Gray-white on fresh and weathered surfaces. Slightly greenish at top. Arkosic. Contains angular to subangular quartz, feldspar, and abundant mica (mostly biotite). Pebbles of quartz, chert, and andesite?	

up to ½ inch diameter at upper contact. Fair sorting. Well compacted. No cement. Porosity and permeability high. Concretionary. Cavernous and spheroidal weathering

4 feet shale. Silty to sandy. Dark gray on fresh surface, iron-stained on weathered surface. Contacts with sandstone sharp. Contains a few poorly preserved Foraminifera and Radiolaria (Loc. M-271)

260 feet sandstone. Massive, friable, medium- to coarse-grained. Gray to buff, weathering gray. Arkosic. Angular to subangular quartz, feldspar, mica (mostly biotite), and a few well rounded grains of black chert or quartzite up to 2 mm. diameter. Well sorted. Well compacted. No cement. Porosity and permeability high. Concretionary. Cavernous and spheroidal weathering

Member 2 27

27 feet shale. Gray. Lumpy to nodular. Abundant Foraminifera and Radiolaria (Locs. M-272 and M-273)

Member 3 552

165 feet sandstone. Massive, friable, medium- to coarse-grained. Buff to gray on fresh and weathered surfaces. Arkosic. Angular to sub-round quartz, feldspar, abundant mica, and here and there well rounded chert or quartzite up to 2 mm. diameter. Well sorted. Well consolidated. No cement except in vicinity of occasional calcite veinlets. Some shaly sandstone beds 6 inches to 1 foot thick with extremely abundant fine mica

3 feet shale. Lumpy, gray, silty. Sandy at top. Contacts sharp. Contains Foraminifera and Radiolaria (Loc. M-274)

42 feet sandstone. Massive, friable, medium- to coarse-grained. Gray to buff on fresh and weathered surfaces. Angular to sub-round quartz, feldspar, and abundant mica. Arkosic. Well sorted. Well consolidated. No cement. Outcrops poor

8 feet shale. Lumpy, gray, silty, contains some Foraminifera and Radiolaria (Loc. M-275)

334 feet sandstone. Massive, friable, medium- to coarse-grained. Gray to buff on fresh and weathered surfaces. Arkosic. Angular to sub-round quartz, feldspar, and abundant mica. Fair to good sorting. Well consolidated. No cement. Cavernous and spheroidal weathering. Abundant concretions and calcareous ledges. Hard ledge at base. Some beds extremely friable

Member 4 160

160 feet shale. Lumpy, gray. Silty to sandy at top, in middle, and in extreme lower part. Some beds brownish and flaky, others hard and almost platy. Abundant, fine mica and much iron stain in many beds. Abundant Foraminifera and Radiolaria in lower third (Locs. M-276, M-277, M-278, M-279). Lower contact obscured. Thickness based on soil examination

Member 5 370

282 feet sandstone. Massive, friable, medium- to coarse-grained. Some beds only slightly friable. Gray to buff on fresh and weathered surfaces. Arkosic. Angular to sub-round quartz, feldspar. Biotite and muscovite common (abundant in some beds with good orientation), some chert. Fair sorting. Well consolidated. No cement. Cavernous and spheroidal weathering. Concretionary. Iron stain prominent in some beds

1 foot shale. Finely laminated. Greenish, rusty brown, silty

1 foot sandstone. Shaly. Rusty brown. Hard calcareous sandstone 6 inches thick at top

1 foot shale. Silty, greenish, rusty brown

85 feet sandstone. Massive, friable, medium- to coarse-grained. Gray to buff on fresh and weathered surfaces. Arkosic. Angular to sub-round quartz, feldspar, with abundant micas in most beds. Iron stain prominent in places. Fair sorting. Well consolidated. No cement. Concretionary. Cavernous and spheroidal weathering

Member 6 65

65 feet shale. Lumpy to nodular, silty to sandy. Greenish gray. Abundant Foraminifera and Radiolaria in upper half. Lower half and lower contact obscured. Thickness based on soil examination (Locs. M-280, M-281, M-282)

Member 7 625

625 feet sandstone. Massive, fine- to coarse-grained. Friable at top but becoming harder and platy toward middle. Gray to buff on fresh and weathered surfaces. Some beds rusty brown on weathered surfaces. Commonly "case-hardened." Fair sorting. Well consolidated. Arkosic. Angular to sub-round quartz, feldspar, with abundant mica in most beds. Cavernous and spheroidal weathering with concretions and calcareous ledges prominent. Lower part more or less obscured by slides.

Temblor thrust fault

Temblor formation (*Oligo-Miocene*).—The Temblor formation, named by Anderson (1905) from the section just east of Carneros Spring, is composed of three

sandstone and three shale members having a total thickness of 1,800 feet, as measured by Kleinpell on Zemorra Creek. These members have been named by various workers as shown in Figure 1, but for this report the nomenclature of Kleinpell (1938) has been followed with the exception of the uppermost sandstone unit. The formation is exposed along the axis of the Carneros syncline, on the flanks of the Carneros anticline, and in a broad band extending southeast from a point where the Carneros anticline dies out. Kleinpell took the lower 380 feet of the Temblor as exposed on Zemorra Creek as the type section for the Zemorrian stage.

The sandstones of the Temblor formation are generally fine- to medium-grained, with the grains varying from sub-round to well rounded. Locally, as in the Carneros sandstone member, the sandstones are coarse-grained to conglomeratic. Unlike the "Tejon," the Temblor sandstones are commonly calcareous and well cemented; only in a few places are they friable. The abundance of glauconite at some horizons, the general paucity of micas, and the abundance of ferromagnesian minerals and dark-colored rock fragments assist in differentiating the sandstones of the Temblor from those of the "Tejon."

The oldest of the members is the lower Temblor shale, also referred to as the "Salt Creek shale," a name which has developed out of local informal usage but has never been properly defined in print or had a type locality designated. It is also sometimes known as the "Purple shale" or "Barren shale." This member is disconformable on the "Tejon" formation in this region and has abundant secondary jarosite at the basal contact. A few poorly preserved casts of Foraminifera have been found in this unit on Zemorra Creek.[3]

The next youngest member is the lower Temblor sandstone, sometimes called the "*Phacoides*" sandstone from the abundance of "*Phacoides*" in a "reef" at its base. This member is probably unconformable on the lower Temblor shale but more work in a larger area is necessary to prove the presence of such an unconformity. On Zemorra Creek the "*Phacoides*" reef lies directly on the lower Temblor shale, whereas at the northwest along Chico Martinez Creek 20 to 30 feet of sandstone was found between the two. On Carneros Creek two or three fossiliferous strata were located in a stratigraphic interval of 40–50 feet. These changes might conceivably be due to thickening or thinning of the beds or to a change of facies, but the possibility of an unconformity should be retained pending further investigation.

Conformable on the lower Temblor sandstone is the "Santos shale" (Gester and Galloway, 1933), named from a locality on Santos Creek a few miles north of Carneros Creek. This member is, in turn, conformably overlain by the Carneros sandstone member (Schenck and von Estorff, 1931; Barbat, 1932), typically exposed in the type section of the Temblor formation near Carneros Creek.

The next youngest member is the "Media shale" (Cunningham and Barbat, 1932) for which a type locality has never been designated, but which is probably

[3] Elmo W. Adams, oral communication, November 16, 1942.

Media Agua Creek. It rests with gradational contact on the Carneros sandstone.

The uppermost member of the Temblor formation is the upper Temblor sandstone or "Button beds" of F. M. Anderson (1905). Cunningham and Barbat placed an unconformity at the base of this member on the basis of supposed *Pholas* borings found in the Carneros Creek section. Kleinpell, however, recognized no such unconformity, and the present writer, largely because of insufficient evidence to the contrary, also believes that this unit is conformable on the "Media shale."

Although the entire Temblor formation is structurally accordant with the subjacent "Tejon," the two formations are notably separated by a disconformity. A foraminiferal faunule collected by Boris Laiming from the lower Temblor shale on Chico Martinez Creek contained a lower Zemorrian assemblage. A sample collected by the writer from the shale 136 feet below the top of the "Tejon" on Zemorra Creek yielded pre-Refugian Foraminifera. Thus, the entire Refugian stage here is missing, unless it is represented by the uppermost 136 feet of the "Tejon," and that possibility seems improbable. The distinct lithologic change between the "Tejon" and the Temblor in this area is also suggestive of an unconformable relationship. The abundant glauconite and phosphatic pellets in the Temblor are not found in the "Tejon," and the grains which make up the sandstones of the "Tejon" are much coarser and more angular than those in the sandstones of the Temblor. McGovney (1942) found similar evidence for an unconformity in an area a few miles south of Zemorra Creek.

The following is a condensed and slightly modified description, after Kleinpell (1938, pp. 105–106), of the Temblor formation at the type locality of the Zemorrian stage.

	Feet
Monterey ("Maricopa") formation	
Temblor formation	1,800
Upper Temblor sandstone	240
50 feet. Coarse-grained calcareous sandstone	
190 feet. More fine-grained, massive sandstone	
"Media shale"	900
160 feet. Silty, brown shale and mudstone	
5 feet. Buff, massive sandstone	
10 feet. Calcareous shale.	
5 feet. Limestone ledges and platy shale	
180 feet. Clay shale	
5 feet. Fine-grained sandstone	
525 feet. Argillaceous shale and mudstone with calcareous stringers	
Carneros sandstone	230
95 feet. Brown, coarse- to medium-grained sandstone	
5 feet. Clay shale	
130 feet. Massive, brown, coarse- to medium-grained sandstone	
"Santos shale"	260
50 feet. Argillaceous shale	
30 feet. Buff sandstone. Uppermost unit of type Zemorrian stage	
130 feet. Lumpy, argillaceous shale. Some glauconite	
50 feet. Foraminiferal argillaceous shale. Phosphatic material and glauconite	
Lower Temblor sandstone	95
95 feet. Massive, fine- to medium-grained buff sandstone with glauconite and phosphatic pellets. "*Phacoides*," *Pecten*, *Ostrea*, *Bruclarkia*, and worm tubes in "reef" at base	
Lower Temblor shale	75

75 feet. Lumpy, gray to purplish brown, silty shale. This unit taken as lowermost unit of Zemorrian stage at type locality

Disconformity

"Tejon" formation

Monterey ("Maricopa") formation.—The Monterey formation is the youngest formation mapped in this investigation. Only the lowermost member, the Gould shale (Barbat, 1932), was examined. In his original definition of the member Barbat placed it in the Temblor formation on the basis of paleontologic evidence. Kleinpell returned it to the Monterey. Because of its lithologic similarity to Monterey, the pronounced lithologic break at its base, and the original designation of the "Button beds" as the uppermost member of the Temblor formation the present writer concurs with Kleinpell in returning the unit to the Monterey.

STRUCTURE

In the Temblor Range folds and faults generally follow the northwest-southeast trend which is common to all of the Coast Ranges of California. These structures, however, do not conform with the trend of the topographic features but trend slightly more toward the west. On the west side of the range and bounding the Carrizo Plain is the San Andreas fault zone. The structural axes in the range roughly parallel this zone or intersect it at an acute angle. Structures in the Chico Martinez Creek area conform with the regional trend, with the exception of the north-south zone of cross-faulting near Carneros Creek.

Folds.—Folds in the Chico Martinez Creek include the faulted Carneros anticline, the Carneros syncline, and the overturned and faulted Chico Martinez anticline.

The Chico Martinez anticline, along the southwestern edge of the area mapped, has been overturned and faulted by the Temblor thrust fault. Since only the units exposed on the east limb of this anticline were examined, the axis is not indicated on the map.

The Carneros anticline, in the northwest quarter of the area mapped, is a southeast-plunging fold. The structure dies out about 4,800 feet west of the NE. corner of Sec. 9. Rocks of the "Tejon" are exposed at and near the crest and those of the Temblor on the flanks. The anticline is faulted along the crest. The exact nature of the fault was not determined, but it could be either a pivotal fault or a reverse fault which dies out down the plunge of the structure.

The Carneros syncline is southwest of the Carneros anticline and is also a southeast-plunging structure. The Carneros sandstone member of the Temblor is exposed along the axis and older Oligo-Miocene and Eocene beds on the flanks. This fold also dies out down the plunge at a point about 4,800 feet west of the NE. corner of Sec. 9. Near Carneros Creek the syncline has been offset by the Cardinal fault zone. The small syncline in the northwest corner of the area mapped is believed to be that northwest part of the Carneros syncline which has been offset.

Faults.—Three principal faults were mapped in the Chico Martinez Creek

area. They are the Carneros fault (along the crest of the Carneros anticline), the Temblor thrust fault (along the overturned Chico Martinez anticline), and the Cardinal fault zone near Carneros Creek.

The Carneros fault is probably either a pivotal fault or a reverse fault which dies out down the plunge of the anticline. Movement appears to have been greatest at or near Carneros Spring and diminishing down the plunge of the anticline, with little or no movement apparent near the site of the abandoned J.R. Kennedy well No. 1. The amount of displacement near Carneros Creek is in the magnitude of a few hundred feet. The presence of this fault is suggested by the extreme change in dip across the axis of the Carneros anticline. The offset of member 2 of the "Tejon" formation is additional evidence.

The Temblor thrust fault was so named by McGovney (1942) who traced it southeastward from Zemorra Creek through Section 16 and as far as the southern boundary of Section 22. The present writer has traced it northwestward through the SW. $\frac{1}{4}$ of Sec. 9, the NE. $\frac{1}{4}$ of Sec. 8, and into Sec. 6. This fault is a thrust on an overturned anticline, with a displacement of approximately 1,000 feet. The fault plane, as observed, has a dip of 20° to 30° SW. The presence of this fault was determined by a difference in attitudes: nearly horizontal "Tejon" beds overlying vertical or overturned beds of the same formation. The discovery of a zone of gouge at several localities along the supposed fault plane confirmed the presence of the fault. Further evidence is furnished by members 4, 5, and 6 of the "Tejon" formation on and near the upper part of Chico Martinez Creek which have attitudes entirely different from those of the beds in the normal section farther down the creek (Fig. 2).

The Cardinal fault zone is best observed in or near a gulch, here named Cardinal Gulch, about $\frac{1}{4}$ mile long which runs southeast through the NE. $\frac{1}{4}$ of Sec. 6 and the NE. $\frac{1}{4}$ of Sec. 5. The fault zone extends north and south in the area mapped, nearly along the west border of Secs. 5 and 8. The several faults in this zone appear to delimit a downthrown wedge block, but with some horizontal movement. It is thought that the zone is due to cross-faulting resulting from movement on the San Andreas fault at the west, but more work in a wider area would be necessary to prove this. Topographic evidence for the faulting is poor in the field, but the trace of the faults may readily be seen on the aerial photographs. Geologic evidence for the existence of the zone may be found in the offset of the "*Phacoides*" reef in and near Cardinal Gulch, on Carneros Creek, and on the north fork of Chico Martinez Creek. Fragments of the overthrust block of the Temblor thrust fault were also found to be offset in this local area.

Unconformities.—At the base of the Temblor formation is a disconformity which represents a hiatus of considerable magnitude. The contact between the lower Temblor shale and the lower Temblor sandstone is possibly also disconformable. Evidence for both of these relationships has been cited in the section on stratigraphy.

Tectonic history.—Though it is difficult to generalize on tectonic history from

such a small area as has been studied in this investigation, by making use of the reports and maps of Arnold and Johnson, English, Reed and Hollister, and others certain inferences may be drawn with reasonable confidence.

Local deformation occurred in pre-Refugian time, but the principal period of diastrophism came in the late Cenozoic prior to the deposition of the McKittrick formation. All beds older than the McKittrick formation have been involved in regional folding, whereas the McKittrick lies on them with marked angular discordance.

Compressive forces of this last period of diastrophism came from the northeast and southwest. Overturning toward the northeast in many places in the Temblor Range shows that locally the greater pressure came from the southwest. Faulting on the Temblor thrust and Carneros faults probably occurred late in the folding.

The Cardinal fault zone is later than the main period of diastrophism since it cuts across and offsets folds which were formed during that epoch. Possibly this faulting occurred during the Pleistocene, when deformation affected a large part of the Coast Ranges (the Pasadenan orogeny of Stille). Faulting along this zone may also have increased the displacement on the northwest end of the Carneros fault.

PALEONTOLOGY

In the Chico Martinez Creek area the paleontologic record is incomplete insofar as the abundance of megafossils is concerned. The entire Eocene section was found to be barren of megafossils, though a more careful search might conceivably unearth a few isolated specimens. The Oligo-Miocene sandstones yielded poorly preserved specimens of several genera. In the so-called "*Phacoides*" reef at the base of the lower Temblor sandstone, *Acila* sp., *Bruclarkia* sp., *Crepidula* sp., *Chlamys branneri* (Arnold), *Lucinoma acutilineata* (Conrad) (often referred to as "*Phacoides*"), and *Miltha sanctæcrucis* (Arnold) were found at several localities. In the Carneros sandstone, Schenck and F. von Estorff collected *Balanus* sp., *Ostrea titan* (auctores), and at least two species of *Pecten*. Specimens of *Echinarachnius merriami* (Anderson) abound in the upper Temblor sandstone ("Button beds") where they are associated with *Pecten andersoni* and *Ostrea*.

The Eocene shale members in this region contain abundant foraminiferal assemblages. Fossiliferous samples were taken on Zemorra Creek, Chico Martinez Creek, and Carneros Creek (Figs. 3 and 4). The recognition of several distinctive and mutually associated species, such as *Bulimina pupula* Stache, *Cibicides sp.D* of Cushman and McMasters, and *Uvigerina churchi* Cushman and Siegfus, aided materially in mapping by assuring the correct correlation of beds across faults and folds. The identifications which were made with the assistance of Lois T. Martin and R. Stanley Beck are tentative, pending further research and the description of numerous species.

Examination of the Eocene foraminiferal assemblages from the Zemorra Creek section has resulted in certain inferences about depositional conditions. Paleoecology is considered to be a preliminary step in the correlation with as-

semblages from other areas. These studies which are based on papers cited in the bibliography deal with bathymetric and thermal distribution, and the distribution of families on the basis of the number of species represented. The results

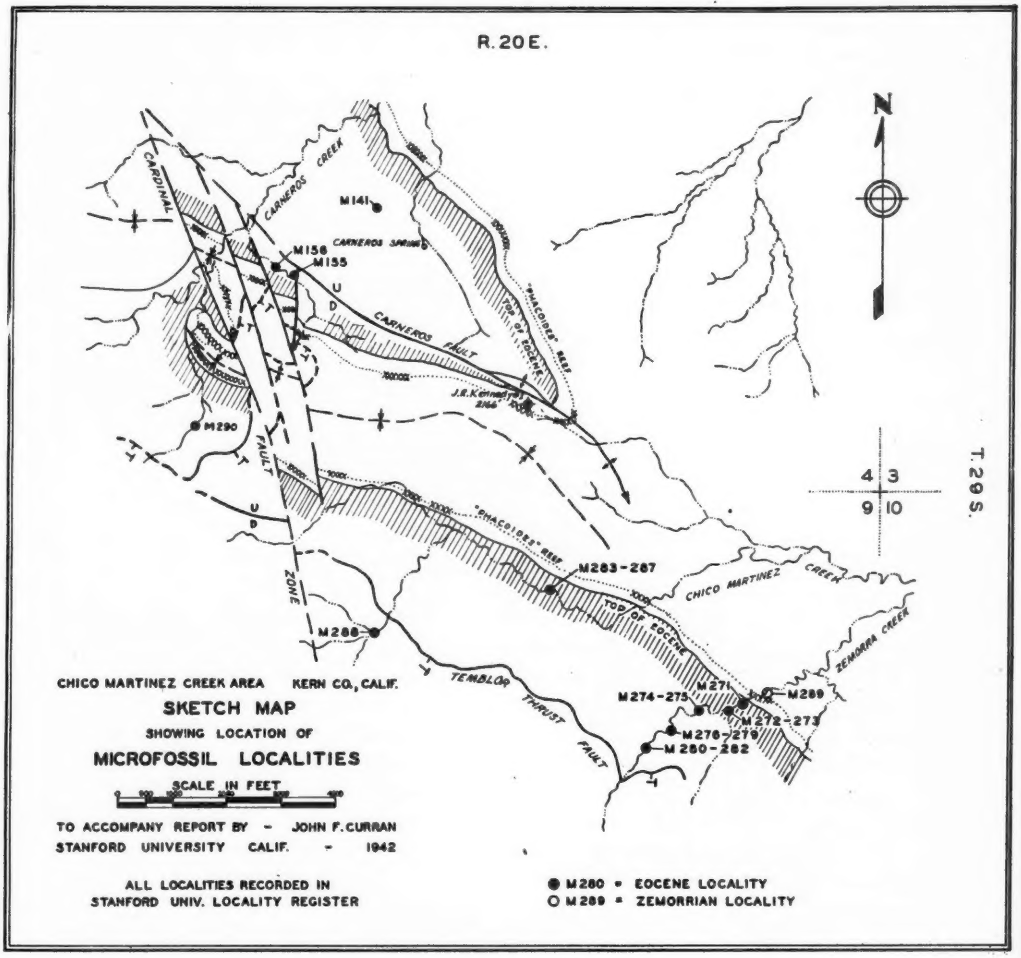


FIG. 4.—Sketch map showing structure and microfossil localities.

are plotted in Figures 6, 7, and 8. The analyses are confined to the samples from member 2 of the "Tejon" formation from Zemorra Creek because they seemed to be fairly representative of the section, and because too many faunules would

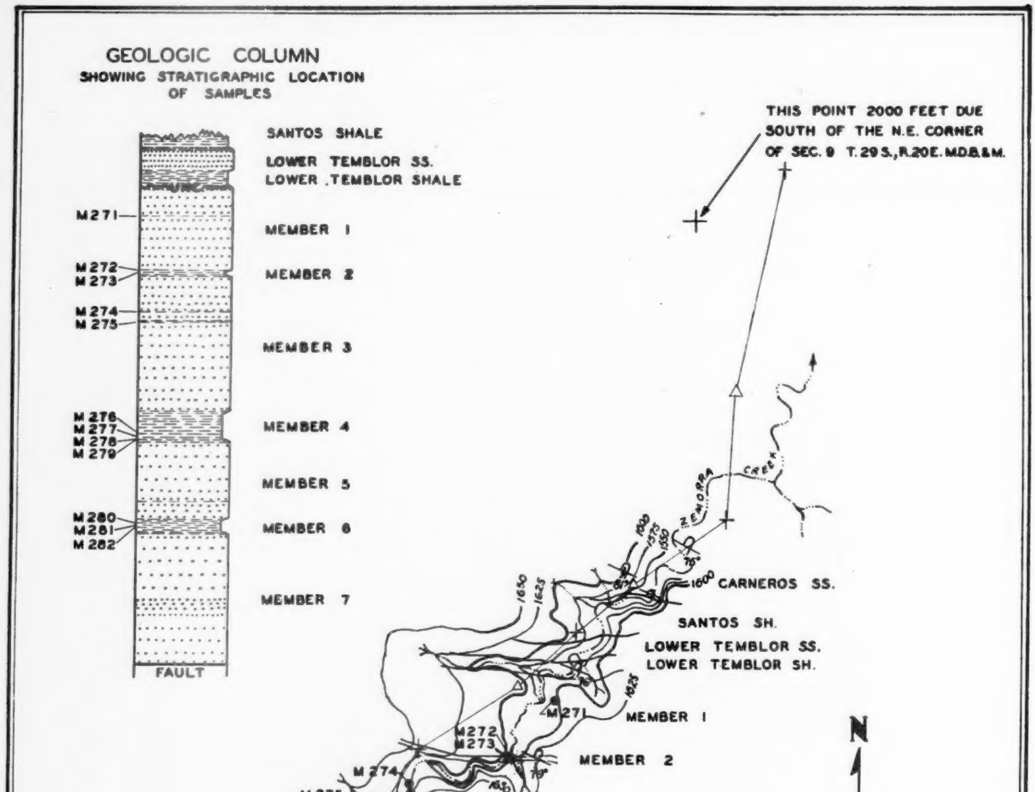


FIG. 5.—Geologic map of part of Zemorra Creek.

distort the picture. Numerous other species appear in samples from the lower part of the section, but the distribution by families appears to be nearly the same.

All of the Eocene samples contain abundant *Radiolaria* of the legion Spumellaria, order Sphaeroidea, family Liosphaerida, and order Discoidea, family Phacodiscida. These are associated with numerous specimens of *Globigerina triloculinoides* Plummer, and members of the families Buliminidae, Lagenidae, and other Foraminifera. Judged from the recent distribution of such organisms, the presence of these fossils indicates open-sea conditions in subtropical or tropical waters during this epoch of the Eocene. The absence of members of the legion Nassellaria of the Radiolaria tends to confirm this conclusion. In the foraminiferal assemblages from member 2 the combination of pelagic genera occurring with neritic, bathyal, abyssal, and benthonic forms in the same sample is indicative of a variety of ecologic conditions within a limited area. Several arenaceous genera indicate a sandy substratum at the time of deposition. The predominance of two or three families of Foraminifera has led to several inferences concerning the ecology and conditions of deposition for the entire assemblage.

Although the majority of genera investigated have a wide bathymetric range there are five or six limiting genera (Fig. 6). Species of the genus *Lenticulina* are not reported in present oceans at depths less than 45–50 fathoms and those of the genera *Robulus* and *Gyroidina* at less than 20 fathoms. Members of the Lagenidae, such as *Robulus* and *Lenticulina*, attain their maximum development off tropical coasts in cold water at depths of 100–500 fathoms. Maximum depths are not as indicative in the case of many fossil Foraminifera as they are in Recent forms since the test may have fallen to greater depths after the death of the animal. However the fact that such genera as *Dorothia*, *Textularia*, and *Tritaxilina* do have maximum depths up to 500 fathoms should not be ignored. Thus, the evidence here seems to point to the deposition of member 2 at not less than 20 fathoms and probably at greater than 100 fathoms.

The limiting genera with regard to temperature (Fig. 7) are *Robulus*, *Textularia*, *Tritaxilina*, and *Ammobaculites*. Maximum temperatures are limited to 57° or 58° F. by *Robulus*, *Ammobaculites*, and *Tritaxilina*. Although the maximum temperature shown on the chart for *Haplophragmoides* is 50°F., information concerning its true temperature range is too inadequate to warrant the inclusion of the genus as a limiting form in this analysis. Minimum temperature is that shown for *Tritaxilina* at 45°F. Thus, the limiting temperatures for the assemblage are 45° and 58°F., but because of the wide bathymetric range these temperatures do not apply to the entire assemblage. Here again the evidence points toward deposition where waters of medium depth are cool but not cold.

In compiling the necessary data for the percentage distribution chart (Fig. 8), Cushman's classification was followed and the percentage figures were computed from the number of species from each family represented by specimens in the assemblage. The family Lagenidae is represented by sixteen species, the Buliminidae and Anomalinidae by nine each, the Rotaliidae by five, the Heterohelicidae

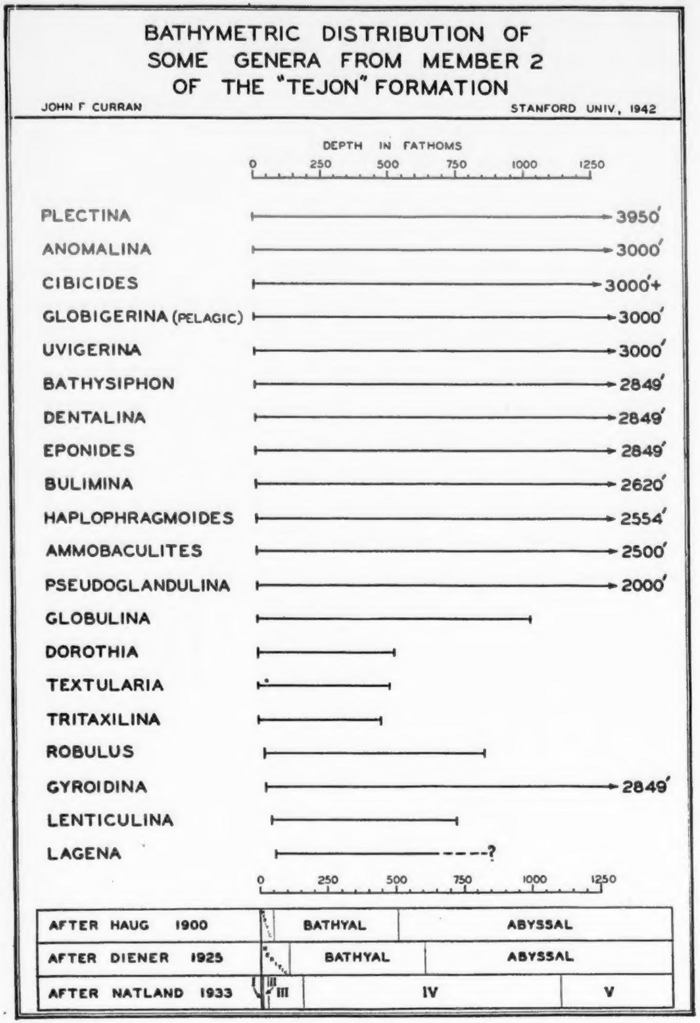


FIG. 6.—Bathymetric distribution chart.

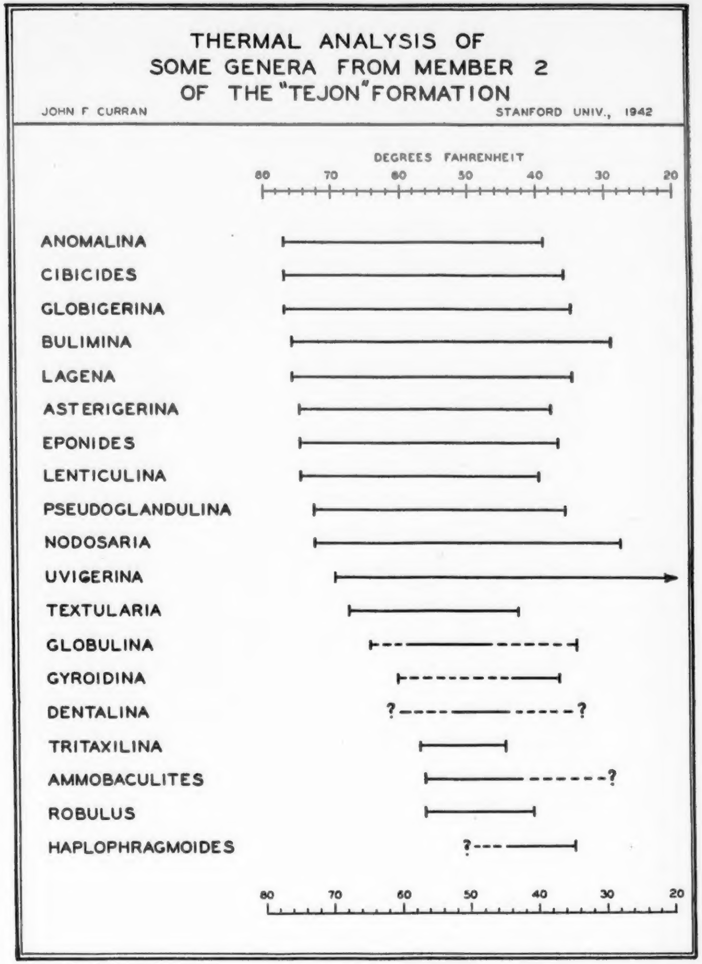


FIG. 7.—Thermal analysis chart.

by three, the Polymorphinidae, the Ellipsoidinidae, the Cassidulinidae, and the Chilostomellidae by two each, and the Rhizamminidae, the Ammodiscidae, the Silicinidae, the Nonionidae, the Amphisteginidae, and the Globigerinidae by

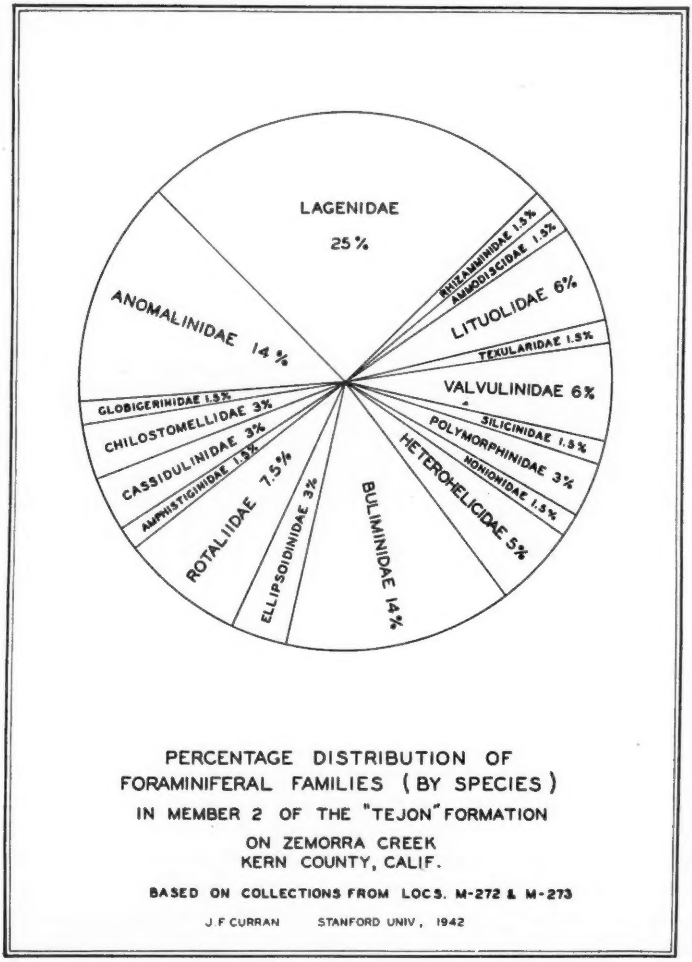


FIG. 8.—Percentage distribution chart, member 2, "Tejon" formation.

one each. The chart shows that 53 per cent of the entire assemblage in member 2 is represented by only three families, the Lagenidae, the Buliminidae, and the Anomalinidae. A review of the ecology of Recent Foraminifera suggests that this

CHECKLIST OF FORAMINIFERA
ZEMORRA CREEK SECTION - CHICO MARTINEZ CREEK AREA
KERN COUNTY, CALIF

JOHN F. CURRAN STANFORD UNIV., 1942

SPECIES	M-271	M-272	M-273	M-274	M-275	M-276	M-277	M-278	M-279	M-280	M-281	M-282
Bathysiphon eocenica Cushman & G.D. Hanna	X	X	X	X	X	X	X	X	X	X	X	X
Robulus inornatus (d'Orbigny)	?	X	X	X	X		X	X	X	X	X	
Textularia cf. mississippiensis Cushman var. rhomboidea Cushman & Ellisor	X	X	X		X		X		X			
Tritaxilina colei Cushman & Siegfus	X	X	X	X	X		X			X	X	X
Ammobaculites cubensis Cushman & Bermudez		X										
Anomalina crassisepta Cushman & Siegfus		X	X		X							
Bolivinopsis eocenicus (Cushman & Barksdale)		X		X	X	X			X	X	X	
Bulimina lirata Cushman & Parker		X	X				X	X				
Bulimina n.sp. Martin		X										
Dentalina obliquisuturata Stache		X	X		X							
Globigerina triloculinoides Plummer		X	X	X	X		X	X	X	X	X	X
Gumbelina striata (Ehrenberg) of Cushman & Dusenbury		X										
Nodosaria arundinea of authors		X		X	X		X					X
Pseudoglandulina ovata Cushman & Applin		X	X		X		X		X	X		
Robulus Species A		X	X					X				
Uvigerina churchi Cushman & Siegfus		X	X									
Uvigerina garzaensis Cushman & Siegfus		?	X	X	X	X						
Asterigerina crassaformis Cushman & Siegfus			X	X	X			X	X	X		
Bolivinopsis directus (Cushman & Siegfus)			X		X	X	X			X	X	
Bulimina corrugata Cushman & Siegfus			X		?		X	X	X	X	X	
Bulimina ovata d'Orbigny			X	X	X		X	X	X	X	X	
Bulimina pupula Stache			X									
Cibicides Sp.D of Cushman & McMasters			X	X							X	
Cibicides pygmaeus (Hantken)			X	X								
Darbyella wilcoxensis Cushman & Garrett			X									
Dentalina colei Cushman & Dusenbury			X						X	X		
Dorothia principensis Cushman & Bermudez of Cushman & Siegfus			X	?	X		X		?	X	X	X
Dorothia Species A			X	X	X		X	X	X			
Eponides umbonatus (Reuss)			X		X		X	X	X	X	X	X
Globulina Species A			X									

concentration of an assemblage into these three families is common only in cool water at depths greater than 100 fathoms, and it may be assumed that during Eocene time the same conditions prevailed. The inference follows that member 2 of the "Tejon" formation was deposited in cool water near or below the edge of the continental shelf.

Finally, although any conclusions reached through a study of the foregoing analyses must be tentative, one may assume that they are essentially correct since all three analyses point to the same or similar conditions. Thus, member 2 of the "Tejon" formation was probably deposited in cool water at or below the edge of the continental shelf at a latitude where surface waters were of a tropical or subtropical nature. This inference taken together with the coarseness, angularity, and freshness of the material in the sandstones of the "Tejon" and the predominance of these sandstones in the section suggest a rapid derivation of

Gyroidina obliquata Cushman & [illegible]			X	X	X		X	X	X		X		
Haplophragmoides coalingensis Cushman & G.D. Hanna			X		X					X		X	
Haplophragmoides eggeri Cushman			X	X	X	X			X	X	X		
Lagena conscripta Cushman & Barksdale			X	X	X								
Lenticulina convergens (Bornemann)			X				X		X				
Plectina garzaensis Cushman & Siegfus			X	X	X			X	X	X		X	
Robulus pseudovortex Cole			X										
Nodosaria nuda Terquem				X	X								
Silicosigmoilina californica Cushman & Church				X	X		X	X			X	X	
Ammodiscus incertus (d'Orbigny)					X			X		X	X		
Anomalina garzaensis Cushman & Siegfus					X		X	X	X				
Cassidulina globosa Hantken					X		X	X	X				
Cibicides pachyderma Rzehak					X		X	X	X		?		
Cibicides venezuelanus Nuttall					X				X			X	
Dentalina consobrina d'Orbigny					X			X					
"Marginulina" asperuliformis (Nuttall)					X								
Pleurostomella nuttalli Cushman & Siegfus					?			X					
Pseudoglandulina conica (Neugeboren)					X								
Pullenia eocenica Cushman & Siegfus					?		X						
Pullenia quinqueloba (Reuss)					X								
Virgula zetina Cole of Cushman & McMasters						X							
Cibicides n.sp. Martin							X	X	X	X		X	
Eponides minimus Cushman							X		X				
Globulina Species B							X						
Nodosaria velascoensis Cushman							X						
Nodosarella advena Cushman & Siegfus							X		X				
Nonion aff. wilcoxensis Cushman & Ponton							X	X	X				
Pulvinulinella tenuicarinata Cushman & Siegfus							X						
Anomalina Species A								X	X	X			
Bulimina pupoides d'Orbigny								X					
Gyroidina octocamerata Cushman & G.D. Hanna								X					
Bulimina denticulata Cushman & Parker									X				
Cibicides cf. nassei Cole of Cushman & Dusenbury										X			
Haplophragmoides excavata (Cushman & Waters)										X	X	X	
Robulus pseudocostatus (Plummer)											X		
Eponides lotus (Schwager)												X	

FIG. 9.—Checklist of Foraminifera, Zemorra Creek.

detritus from a rugged landmass and deposition in a sea having a steeply sloping bottom profile. Such conditions might well account for the absence of megafossils in the "Tejon."

These inferences have been set forth with a full realization of the inadequacy of the basic data. For example, ecologic information was taken from publications in which depths and temperatures varied widely for different studies, and in which, in some cases, the work was obviously incomplete. Moreover, few workers have applied the "protoplasm test" to determine whether the animals under consideration lived and died where their tests were found.

CORRELATION

In proposing a correlation between the Eocene beds of the Chico Martinez Creek area and the strata of near-by areas "Jordan's law" was kept in mind. This

principle of David Starr Jordan states that the most closely related species are likely to be found in adjacent areas, not within the same area or distant areas. By extension, this principle can be applied to the distribution of organisms in time.

Thus, a correlation with the Devil's Den shale at its type locality was attempted first. This locality is only about 20 miles north of Chico Martinez Creek. A comparison of the checklist of the Zemorra Creek Eocene species and the checklist of species from the Devil's Den shale shows that there are twenty species in common. However, only two of these species are among those restricted to the upper part of the Zemorra Creek section. Hence, it might be assumed that the lowest "Tejon" beds of Zemorra and Chico Martinez creeks are equivalent in age to the Devil's Den shale in whole or in part, and that the correlatives of the upper members of the "Tejon" of Zemorra Creek are absent from the Devil's Den area because of a supposed unconformity. A more likely hypothesis is that the "Tejon" was deposited at the same time as the Point of Rocks sandstone. Since complete paleontologic control is lacking, further attempts at correlation were discontinued.

The next closest Eocene locality is the type locality of the Kreyenhagen shale on Reef Ridge, Fresno and Kings counties, 20 miles north of Devil's Den and approximately 40 to 45 miles north of Chico Martinez Creek. The combined work of Boris Laiming (1939), R. W. Crume (1940), E. A. Watson (1941), and Cushman and Siegfus (1942) in the Reef Ridge district was used to make the correlations. Analysis of the checklists from these papers and an examination of the species occurring in Laiming's zones prove that more than 50 per cent of the Zemorra Creek Eocene fauna is present in Laiming's "A" zones. Therefore, the beds in the Zemorra Creek section are younger than Domengine or Avenal. The discovery of eight species of corals of Domengine age by J. Wyatt Durham (1942) in Media Agua Creek, a few miles north of Zemorra Creek and slightly lower in the section than the Zemorra Creek strata, is further proof of the post-Domengine age of members 1–7 of this report.

An analysis of the percentage distribution of foraminiferal families represented by species in the checklist of Cushman and Siegfus (Fig. 11) shows that 47 per cent of the species identified are members of the families Lagenidae, Buliminidae, and Anomalinidae. This is favorably comparable with the analysis of the Zemorra Creek Eocene assemblage in which 53 per cent of the total number of species are members of these three families. The dominance of these medium-depth, cool-water forms in both assemblages suggests that ecologic conditions were similar during the period of deposition in both areas. Distinctive calcareous foraminifers, therefore, should be reliable time markers.

An inspection of the combined checklists of Crume, Watson, and Cushman and Siegfus discloses that thirty-one species are in common with the Zemorra Creek section. As three are arenaceous, they are relatively unreliable in fine-spun synchronization of beds. Thirteen occur in formations older than the Canoas

CHECKLIST OF FORAMINIFERA
MISCELLANEOUS LOCALITIES - CHICO MARTINEZ CREEK AREA
KERN COUNTY, CALIF

JOHN F. CURRAN — STANFORD UNIV., 1942

SPECIES	M-283	M-284	M-285	M-286	M-287		M-155	M-156		M-141		M-288	
Bathysiphon eocenica Cushman & G.D.Hanna	X	X	X	X	X							X	
Bolivinopsis directus (Cushman & Siegfus)	X	X	X				X					X	
Bulimina corrugata Cushman & Siegfus	?	X	X	X								X	
Bulimina taylorensis Cushman & Parker	?									?			
Cibicides venezuelanus Nuttall	X												
Dorothia principensis Cushman & Bermudez of Cushman & Siegfus	X									X		X	
Eponides umbonatus (Reuss)	X	X										X	
Globogerina triloculinoides Plummer	?	X		X			X	X		X			
Haplophragmoides eggeri Cushman	X	?	X		X							X	
Lagena conscripta Cushman & Barksdale	X											X	
Robulus inornatus (d'Orbigny)	X		X	X									
Robulus Species A	X		X										
Spiroplectammina n.sp. Martin	X												
Tritaxilina colei Cushman & Siegfus	X	X	X		X		X	X		X		X	
Uvigerina churchi Cushman & Siegfus	X	?	X	X			X			X			
Uvigerina garzaensis Cushman & Siegfus	X	X		X				X		X			
?Virgulina cf. zetina Cole of Cushman & McMasters	X												
Anomalina crassisepta Cushman & Siegfus		X		X				X				X	
Bulimina lirata Cushman & Parker		X		X						?			
Dentalina colei Cushman & Dusenbury		X											
Dentalina obliquisuturata Stache		X		X									
Eponides pygmaeus Hantken		X		X									
Gümbelina striata (Ehrenberg) of Cushman & Dusenbury		X		X									
Textularia cf. mississippiensis Cushman var. rhomboidea Cushman & Ellisor		X	X	X									
Dorothia Species A			X									X	
Haplophragmoides coalingensis Cushman & G.D. Hanna			X		X								
"Marginulina" asperuliformis (Nuttall)			X										
Cassidulina globosa Hantken				X									
?Haplophragmoides excavata Cushman & Waters				X									
Asterigerina crassaformis Cushman & Siegfus							X	X		X		X	
Globulina Species A							X	?					
Pseudoglandulina ovata Cushman & Applin								X					
Pullenia quinqueloba (Reuss)								X					
Cibicides n.sp. Martin												X	
Eponides minimus Cushman												X	
Globigerina bulloides d'Orbigny												X	
Guttulina hantkeni Cushman & Ozawa												X	
Gyroidina octocamerata Cushman & G.D.Hanna												X	
Lagena hexagona												X	
Nodosarella ignota Cushman & Siegfus												X	
Plectina garzaensis Cushman & Siegfus												X	
Pleurostomella nuttalli Cushman & Siegfus												X	
Pullenia eocenica Cushman & Siegfus												X	
Pulvinulinella tenuicarinata Cushman & Siegfus												X	
Saracenaria sp.												X	
Silicosigmoilina californica Cushman & Church												X	

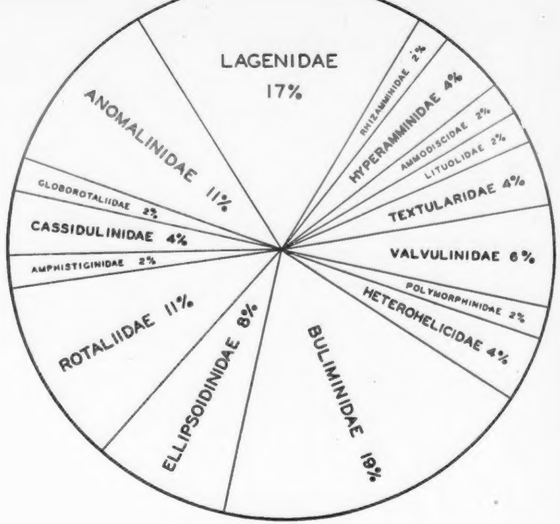
Localities M-283 to M-287 - Member 2 of "Tejon" fm., Chico Martinez Creek
Localities M-155 & M-156 - Member 2 of "Tejon" fm., Cardinal Gulch
Locality M-141 - Member 2 of "Tejon" fm., Carneros Spring
Locality M-288 - Member 6 of "Tejon" fm. west of Temblor Thrust Fault, Chico Martinez Creek

FIG. 10.—Checklist of Foraminifera, miscellaneous localities.

SPECIES	KREYENHAGEN SAGASAR	KREYENHAGEN CANOAS	"TEJON" MEMBER 2	"TEJON" MEMBER 3	"TEJON" MEMBER 4	"TEJON" MEMBER 6
Anomalina crassisepta Cushman & Siegfus (3)	X	X	X	X		
Anomalina garzaensis Cushman & Siegfus (3)	X	X		X	X	
Asterigerina crassaformis Cushman & Siegfus (3)	X	X	X	X	X	X
Bathysiphon eocenicus Cushman & G.D.Hanna (1,2)	X	X	X	X	X	X
Bolivinopsis directus (Cushman & Siegfus) (3)	X	X	X		X	X
Bulimina corrugata Cushman & Siegfus (3)	X	X	X	?	X	X
Bulimina lirata Cushman & Parker (3)	X	X	X		X	
Cibicides Sp.D of Cushman & McMasters (2)	X	X	X	X		
Cibicides venezuelanus Nuttall	X	X	X	X		
Dentalina consobrina d'Orbigny (2,3?)	X	X		X	X	
Dorothia principensis Cushman & Siegfus of Cushman & Siegfus (1,3)	X	X	X	X	X	X
Eponides minimus Cushman (2)	X	X			X	
Eponides umbonatus (Reuss) (2)	X	X	X	X	X	X
Gyroidina octocamerata Cushman & G.D.Hanna (2)	X	X			X	
Lenticulina convergens (Bornemann) (2)	X	X	X		X	
Plectina garzaensis Cushman & Siegfus (1)	X	X	X	X	X	X
Pulvinulinella tenuicarinata Cushman & Siegfus (	X	X			X	
Robulus pseudovortex Cole (2)	X	X	X			
Tritaxilina colei Cushman & Siegfus (1,3)	X	X	X	X	X	X
Uvigerina churchi Cushman & Siegfus (3)	X	X	X			
Bolivinopsis eocenicus (Cushman & Barksdale) (2)		X	X	X	X	X
Cassidulina globosa Hantken (2,3)		X		X	X	
Cibicides pachyderma (Rzehak)		X		X	X	?
Cibicides sassei Cole of Cushman & Dusenbury (3)		X				X
Lagena conscripta Cushman & Barksdale (2)		X	X	X		
Marginulina asperuliformis (Nuttall) (3)		X		X		
Nodosarella advena Cushman & Siegfus		X			X	
Pleurostomella nuttalli Cushman & Siegfus (3)		X		?	X	
Pseudoglandulina conica (Neugeboren) (2)		X		X		
Pullenia eocenica Cushman & Siegfus (3)		X		?	X	
Silicosigmoilina californica Cushman & Church (1,2)		X		X	X	X

1. Arenaceous
2. Known in beds older than Canoas
3. Occurs in Laiming's "A" zones

FIG. 11.—Checklist of Foraminifera common to Kreyenhagen, Fresno and Kings counties, and "Tejon" formation, Zemorra Creek, Kern County.



PERCENTAGE DISTRIBUTION

OF FORAMINIFERAL FAMILIES (BY SPECIES)

CANOAS SILTSTONE MEMBER, KREYENHAGEN FM.

REEF RIDGE, FRESNO & KINGS COUNTIES, CALIF.

BASED ON IDENTIFIED SPECIES IN CUSHMAN & SIEGFUS, 1942

JOHN F. CURRAN STANFORD UNIV., 1942

FIG. 12.—Percentage distribution chart, Canoas siltstone, Kreyenhagen formation.

siltstone member of the Kreyenhagen. Fifteen are present in Laiming's "A" zones. Further inspection shows that eleven of the thirty-one species are absent in beds younger than the Canoas on Reef Ridge, and fourteen appear in rocks older than member 2 of the "Tejon" on Zemorra Creek. Of the eleven species restricted to the Canoas, all but three are present in the lower part of the Zemorra Creek section, whereas all of the species from member 2 and fourteen from member 3 appear in the Sagasar shale member (Crume, 1940) of the Kreyenhagen. It appears, therefore, that members 1 and 2 and the upper part of member 3 are equivalent in age to the Sagasar shale, and that the lower part of member 3 and members 4, 5, 6, and 7 are equivalent to the Canoas, the equivalent of the Sagasar-Canoas boundary being probably in the lower part of member 3.

Notwithstanding the provisional identifications of all species, the information available indicates the simultaneous deposition of the Kreyenhagen siliceous shale and the "cavernous-weathering sandstone" of the Chico Martinez Creek–Carneros Creek district.

Attempted correlation of the "Tejon" of Zemorra Creek with the type Tejon formation was unsuccessful. Direct comparison of foraminiferal assemblages revealed no similarity and only a few species were found to be common to both formations.

REGISTER OF MICROFOSSIL LOCALITIES

All localities are within T. 29 S., R. 20 E., M.D.B. & M. of the McKittrick Quadrangle, Kern County, California. Localities are recorded in the Stanford University locality register.

M-271
Location: Zemorra Creek. 4,320 feet south and 680 feet west of NE. corner of Sec. 9
Formation: Member 1, "Tejon" formation, Eocene
Collectors: H. G. Schenck and J. F. Curran, October, 1941

M-272
Location: Zemorra Creek. 4,590 feet south and 900 feet west of NE. corner of Sec. 9
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-273
Location: Zemorra Creek. 10 feet stratigraphically below M-272
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-274
Location: Zemorra Creek. 4,720 feet south and 1,395 feet west of NE. corner of Sec. 9
Formation: Member 3, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-275
Location: Zemorra Creek. 4,770 feet south and 1,383 feet west of NE. corner of Sec. 9
Formation: Member 3, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-276
Location: Zemorra Creek. 5,220 feet south and 1,710 feet west of NE. corner of Sec. 9
Formation: Member 4, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-277
Location: Zemorra Creek. 16 feet stratigraphically below M-276
Formation: Member 4, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-278
Location: Zemorra Creek. 22 feet stratigraphically below M-276
Formation: Member 4, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-279
Location: Zemorra Creek. 25 feet stratigraphically below M-276
Formation: Member 4, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-280
Location: Zemorra Creek. 5,825 feet south and 1,975 feet west of NE. corner of Sec. 9
Formation: Member 6, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-281
Location: Zemorra Creek. 6 feet stratigraphically below M-280
Formation: Member 6, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-282
Location: Zemorra Creek. 14 feet stratigraphically below M-280
Formation: Member 6, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-283
Location: Chico Martinez Creek. 1,749 feet south and 6,170 feet west of NE. corner of Sec. 9
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-284
Location: Chico Martinez Creek. 5 feet stratigraphically below M-283
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-285
Location: Chico Martinez Creek. 10 feet stratigraphically below M-283
Formation- Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-286
Location: Chico Martinez Creek. 15 feet stratigraphically below M-283
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-287
Location: Chico Martinez Creek. 20 feet stratigraphically below M-283
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Curran, October, 1941

M-288
Location: Chico Martinez Creek. 1,252 feet south and 9,213 feet west of NE. corner of Sec. 9
Formation: Member 6, "Tejon" formation, Eocene
Collector: J. F. Curran, March, 1942

M-289
Location: Zemorra Creek. 3,665 feet south and 2,077 feet west of NE. corner of Sec. 9
Formation: "Santos shale" member, Temblor formation, lower Zemorrian
Collectors: Schenck and Curran, October, 1941

M-290
Location: Carneros Creek. 1,166 feet north and 12,595 feet west of NE. corner of Sec. 9
Formation: Member 4, "Tejon" formation, Eocene
Collector: J. F. Curran, March, 1942

M-141
Location: Near Carneros Spring. 5,066 feet north and 9,407 feet west of NE. corner of Sec. 9
Formation: Member 2, "Tejon" formation, Eocene
Collectors: H. G. Schenck and Elmo W. Adams, March, 1940

M-155
Location: Cardinal Gulch. 3,882 feet north and 10,829 feet west of NE. corner of Sec. 9
Formation: Member 2, "Tejon" formation, Eocene
Collectors: Schenck and Adams, March, 1940

M-156
Location: Cardinal Gulch. 4,048 feet north and 11,112 feet west of NE. corner of Sec. 9
Formation: Member 2, "Tejon" formation, Eocene
Colllectors: Schenck and Adams, March, 1940

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VOL. 27, NO. 10 (OCTOBER, 1943), PP. 1387-1392, 1 FIG.

GEOLOGICAL NOTES

REGIONAL GEOLOGIC STUDIES FOR OIL AND NATURAL GAS[1]

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Washington, D. C.

Regional studies in many states where there are promising possibilities for the discovery of new supplies of petroleum and natural gas are being undertaken by the Geological Survey of the United States Department of the Interior. These studies have been provided for by a Congressional appropriation of $300,000 for this purpose during the present fiscal year, beginning July 1, 1943. The different parts of the United States where work is being undertaken include California, the Rocky Mountain region, the Mid-Continent region, the Gulf Coastal Plain, and the Appalachian region. The funds that have been made available to the Geological Survey for this purpose are greater than those for any year in the past, and the resultant expanded geologic program is much greater than any heretofore undertaken by the Geological Survey.

The Survey's program of geologic work is being formulated through collaboration with the oil and gas industry and the State geological surveys, and will include projects that will, so far as possible, supplement and not duplicate the efforts of the oil and gas companies and the State geological surveys. Many State geologists, officers of the American Association of Petroleum Geologists, and the presidents of local geological societies, as well as numerous other geologists, have been consulted thus far, and have been extremely helpful in the selection of projects that will provide data of greatest usefulness in the exploration for oil and gas.

The type of work that is most widely sponsored and is being undertaken is regional stratigraphy, both subsurface and surface, of large areas, such as basins or similar geologic provinces. The studies will be devoted primarily to the accumulation of data for the preparation of maps and stratigraphic sections showing (a) thickness of oil-producing formations, (b) changes in facies or porosity of oil formations or possible oil formations, (c) margins of producing or possible producing zones, (d) relations and extent of lenticular sands. These studies will have as their objective the delimitation of broad areas that are favorable for exploration. The determination of local structural features, whether by surface, subsurface, or geophysical methods, will not be stressed.

The results of the stratigraphic studies in each area will be released promptly through different mediums of publication, including Federal and State geological surveys and the American Association of Petroleum Geologists.

The recruiting of competent geologists to man the present expanded oil and gas program has been difficult because of the war-time demand and consequent

[1] Published with permission of the director of the Geological Survey, United States Department of the Interior.

[2] Geological Survey.

shortage of geologists. Nevertheless, essentially a full staff has been obtained. It has been recruited through the Civil Service Commission, by transfers from other Governmental agencies, educational institutions, and other sources, exclusive of the geologic staffs of the oil and gas companies.

In summary, the Geological Survey's program of oil and gas investigations envisages coöperation with the oil and gas industry and the State geological surveys for the purpose of supplementing, so far as possible, their activities. Also, the program, which involves regional stratigraphic studies, has as its objective the rendering of assistance in the discovery of the supplies of petroleum and natural gas required to meet our present and expected production and demands.

Comment by A. R. Denison, Tulsa, Oklahoma, September 14, 1943.—

The foregoing geologic note is of great interest to all petroleum geologists. This program of regional studies for the purpose of obtaining stratigraphic and structural data in broad provinces and basins is the most extensive program which has been undertaken by the United States Geological Survey since the last war to assist the oil and gas industry in locating new supplies of oil and gas.

In all probability every petroleum geologist has been confronted with a problem which could be solved only by a broad approach: a study of such a nature that no small oil company, and only a very few of the largest oil companies, could afford to undertake it. This new Survey program is designed to start where the average oil-company geologist leaves off, and to carry forward regional studies of such a scope as has been possible in the past only by the coöperative efforts sponsored by some local geological societies.

The appropriation of $300,000 is to be spent by July 1, 1944. When this item was included in the United States Geological Survey budget, it was intimated by certain members of Congress that if additional funds were needed, appropriations could in all probability be provided. This attitude on the part of Congress demonstrates very clearly that our law-making bodies are cognizant of the present needs for discovery of new reserves. They have turned to the United States Geological Survey and have written what can be interpreted as a "blank check" with the admonition to spend this sum wisely and when it is spent "come back for more."

We thus have a situation where the national attitude concerning oil has completely changed. When the European war started the commonly accepted opinion was that all that was needed to provide an ample supply of crude oil was to "turn a valve." There is no doubt that this generally accepted attitude is responsible for a great many restrictions and limitations which have been placed on exploration and drilling. This appropriation to the Survey gives clear testimony to the fact that the early ideas have changed. It may be the sign pointing toward a more liberal attitude on materials, equipment, and personnel needed in exploration and drilling in the oil and gas industry.

THREE MORE GRAPTOLITES FROM SIMPSON OF OKLAHOMA[1]

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INTRODUCTION

Three more graptolites have been collected recently from the upper part of the Bromide, the uppermost formation of the Simpson group at Rock Crossing in the Criner Hills

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in Carter County about 8 miles southwest of Ardmore, Oklahoma. Two of the forms are new species of *Dictyonema* belonging to the Dendroidea, and one described species of *Dicellograptus* belonging to the Graptoloidea.

One *Dictyonema* was collected by a student in the geology department, Frances Coleman (Mrs. Tom Coleman), and that species is named in her honor. The other two species were collected by the writer. The *Dicellograptus* is important for correlation. Also, it has a new extremely important characteristic in the presence of bithecae which hitherto have not been recognized in this genus. The correlative value of this form is noted, and the significance of the discovery by the writer of bithecae in this and two other genera is discussed briefly.

In 1935, the writer (2)[3] illustrated and described *Diplograptus maxwelli* from this upper Bromide zone, and *Didymograptus artus* Elles and Wood and *D. bifidus* Hall from the important zone in the Joins, the lowest formation in the Simpson group. Description of the two new species of *Dictyonema* is followed by that of the *Dicellograptus*.

DESCRIPTION OF SPECIES

Order Dendroidea Nicholson 1872
Genus Dictyonema Hall 1852
Dictyonema francesiae Decker n. sp.
Plate 1, Figure 1

This yellowish brown colony is preserved in fine-grained argillaceous limestone and it apparently never was darkened by carbonization. It occurs about 25 feet below the top of the Bromide formation in the zone with *Ampyx mcgeheei* Decker and just a little below the zone of *Diplograptus maxwelli* in which the *Dicellograptus* occurs.

The colony consists of 8 rugged vertical stipes in the lower part of the colony and 12 in the upper part. The colony is 10 mm. wide and 30 mm. long. The vertical branches are about 0.5 mm. wide and the spaces between them are about the same width or a little wider. The meshes average about 0.5 mm. in width and 2 mm. in length. Dissepiments are moderate in width, and many of them seem to be formed by the extension of elongate thecae.

The obverse side of the colony is preserved so that the thecae are exposed for practically their full length. Thecae of three kinds are present including those for regular polyps, large gonothecae for reproduction, and small elongate bithecae which doubtless housed stinging cells. The regular thecae are small and occur about 24 to 32 in 10 mm., and they are about twice as long as wide. Many of them are nearly normal to the direction of the stipes. Gonothecae are large and swollen, and generally two or more times as large as the regular thecae. Bithecae are narrow and elongate.

Dictyonema rockcrossingensis Decker n. sp.
Plate 1, Figure 2

The specific name of this form is given for the locality, Rock Crossing on Hickory Creek near the south end of the Criner Hills, Carter County, Oklahoma. This species differs greatly from the foregoing species in having less regular vertical stipes, and meshes which are wider in proportion to their length. In these regards it approaches the form of a *Desmograptus*. In the middle of the lower part of the colony some stipes seem to be superimposed on others in a way to suggest an infundibuliform, or funnel shape. Accordingly, only in the upper part, and right third of the lower part of the colony are the natural meshes exhibited. These meshes have an average width of 1 mm. and a length of 2.5 mm. This colony is much darker than the other, and all stipes which have not been partly exfoliated are brownish black.

[3] Figures in parenthesis refer to references at end of paper.

1
2
3
3a
4
5
5a
6

Regular, reproductive, and bithecae are present. Regular thecae occur about 32 to 40 in 10 mm., and they are two to three times as long as wide. The basal part of the colony is missing, and areas of considerable size on it have been completely broken away. The length of the part preserved is 37 mm. and the width 20 mm. Most of the thecae lie at a more acute angle than that of those in the other colony.

Order Graptoloidea Lapworth 1875
Genus Dicellograptus Hopkinson 1871
Dicellograptus gurleyi Lapworth
Plate 1, Figures 3, 3a; 4; 5, 5a; 6

No complete colony has been found, but several large fragments, including two with the proximal end, have characteristics like those of *gurleyi*. Many of the stipes of this species have the stipes twisted, but not all of them are twisted as may be seen in the text figures and plates by Ruedemann (7, p. 303; text Fig. 223; Pl. 19, Figs. 2, 10).

The colony is V-shaped. Two long stipes diverge distally from the proximal or sicular end. The longest stipes found in the Bromide measure 245 mm. in length, and they vary in width from 0.5 to 0.75 mm. At the proximal end they include an angle of 75°–85°. Thecae occur 9 in 10. mm., while in typical specimens, they may occur 9 to 12 in 10 mm.

The writer announces the significant discovery that numerous bithecae occur in this species and in a number of other species of *Dicellograptus*, *Diplograptus*, and *Didymograptus*. The bithecae appear as tiny narrow elongate thecae and as tiny circular apertures. Ruedemann (7, pp. 297–309) has shown a number of these structures, but does not mention their connection with bithecae. In fact, bithecae have been recognized on few of the Graptoloidea, and those profusely branched forms such as *Clonograptus tenellus* and *Bryograptus hunnbergensis* (1, pp. D 65, 69).

Correlation—The writer (3, p. 159) has correlated this upper part of the Bromide with the middle of the Mifflin member of the Platteville of Wisconsin by means of *Diplograptus* (*Amplexograptus*) *maxwelli* Decker. The same species has been recognized in the Ordovician of Sweden by Ekstrom (4). However, because of its early graptolite associates, the writer believes that the Swedish form represents an earlier variety of the species *maxwelli*.

The upper Bromide zone in Oklahoma may be correlated widely by means of *Dicellograptus gurleyi*. According to Ruedemann (7, p. 305) it occurs abundantly in the Normanskill shale of New York, and Miser and Purdue (6) have listed it from the Womble shale of Arkansas. As the top of the Bromide is linked with the Normanskill and Womble, and as 18 species of graptolites found in these two formations occur in the lower part of the Viola

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PLATE 1

(Magnification is ×4 except for 3a and 5a which are ×8)

FIG. 1.—*Dictyonema francesiae* Decker n. sp. showing obverse side with large parts of stipes consisting of closely packed nearly parallel thecae, a few large gonothecae, and small bithecae. Holotype A2062.

FIG. 2.—*Dictyonema rockcrossingensis* Decker n. sp. showing obverse side with the three kinds of thecae noted in Figure 1, but with less continuous vertical stipes and less regular meshes. Crowding of stipes in the lower central part suggests the inclusion there of a few stipes from the opposite side of a funnel-shaped colony. A break in the slab occurs along the position of the dashed line. Holotype A2063.

FIGS.—3, 3a, 4, 5, 5a, 6, *Dicellograptus gurleyi* Lapworth showing 4 fragments of colonies which where complete are V-shaped. The specimen in Figure 5 exhibits a little twisting which is commonly characteristic of the species. The significant narrow elongate structures and small circular openings represent bithecae. These structures are preserved in fine-grained argillaceous limestone. Hypotypes A2064, A2064a, A2064b, A2064c.

Drawings were made by the writer using a camera lucida on a Parkes-Lapworth graptolite microscope.

limestone, Normanskill and Womble are shown to bridge the short hiatus between the Bromide and Viola. Also, this upper Bromide zone can be correlated with the Upper Ordovician of Australia, as Keble and Benson (5) have listed *Dicellograptus gurleyi* from the rocks of that country.

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DISCUSSION

STRATIGRAPHIC TYPE OIL FIELDS[1]

C. W. SANDERS[2]
Houston, Texas

In my article "Stratigraphic Type Oil Fields and Proposed New Classification of Reservoir Traps," which appeared in the April, 1943, issue of the *Bulletin*, reference was made to a paper on the Hitchcock field, Texas, by M. T. Halbouty and Benjamin T. Simmons in the symposium *Stratigraphic Type Oil Fields*. In their paper it was stated that the Hitchcock structure consisted of dips toward the south, west, and north, and that the stratigraphic pinch-out of the producing sand to the east was necessary for the presence of a trap in the Hitchcock area. The presence of *east* dip in addition to the other dips at Hitchcock was stressed in my article in order to show that the wedge-out was not necessary to "complete the trap," but in so doing I may have given the impression that the original authors had purposely withheld data as to the fact that the Hitchcock structure is a dome in the Miocene beds, rather than a mere west-plunging nose. I wish, now, to point out that those authors did not have access to all the data that is available to the present writer, which includes geophysical information, and that their interpretation was reasonable with the data at hand.

[1] Manuscript received, September 11, 1943.

[2] Research geologist, Shell Oil Company, Inc.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 10 (OCTOBER, 1943), PP. 1393-1396.

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

GEOLOGIC FORMATIONS AND ECONOMIC DEVELOPMENT OF THE OIL AND GAS FIELDS OF CALIFORNIA, BY OLAF P. JENKINS ET AL.

REVIEW BY F. M. VAN TUYL[1] AND L. W. LEROY[2]
Golden, Colorado

*"Geologic Formations and Economic Development of the Oil and Gas Fields of California," prepared under the direction of Olaf P. Jenkins. xvi, 773 pp., 301 figs., 81 key maps, 6 pls. 8.5×11 inches. Contains outline geologic map showing oil and gas fields and drilled areas (in pocket). Preprint edition in 4 parts, paper bound. Parts 3 and 4 under one cover. *California Dept. Nat. Res. Div. Mines, Geologic Branch, Bull. 118* (Ferry Building, San Francisco, April, 1940, to March, 1943). Price, $4.00. Final cloth-bound volume (April, 1943), $6.00 (when ready).

Bulletin 118 represents a comprehensive treatise on the geology and oil and gas resources of California prepared over a period of more than 5 years by 126 recognized authorities under the editorial direction of Olaf P. Jenkins, supervising geologist of the Division of Mines of the Department of Natural Resources of the State.

In order to avoid undue delay in the appearance of data on timely topics, a preliminary edition of the report, divided into 4 parts, was published. The first part is dated April, 1940; the second August, 1941; and the third and fourth, which are bound together, March, 1943. In the final edition all parts are to be combined into one volume.

Part 1, "Development of the Industry" (pp. 1–80; 43 figs., 1 pl.), comprises 3 chapters entitled: "Development and Production," "Exploration," and "Early History."

Highlighting this part are the following articles: "Economics on the Oil and Gas Industry of California," by J. R. Pemberton; "Analysis of California Petroleum Reserves and Their Relation to Demand and Curtailment," by William R. Wardner, Jr.; "Development of Engineering Technique and Its Effect upon Exploration for Oil and Gas in California," by Lester C. Uren; "Mechanics of California Reservoirs," by Stanley C. Herold; and "History of Exploration and Development of Gas and Oil in Northern California," by Walter Stalder.

Part 2, "Geology of California and the Occurrence of Oil and Gas" (pp. 81–276; 84 figs., 5 pls., 14 tables), contains 4 chapters: "Introduction to the Geology," "Geologic History and Structure," "Paleontology and Stratigraphy," and "Occurrence of Oil."

In the opening pages Olaf P. Jenkins discusses characteristics and relationships of the geomorphic provinces of the state and summarizes the relationship of mineral deposits to salient geologic events. This is followed by a dissertation by Ralph D. Reed, concerning California oil fields as related to regional structure and a general summary of California stratigraphy. Columnar sections, cross sections and paleogeographic maps accompany the article. N. L. Taliaferro presents his views on the structure, diastrophic history, and certain phases of Jurassic, Cretaceous, and Tertiary stratigraphy of the Central Coast Ranges. The text is supplemented by many excellent cross sections and key maps. Taliaferro has made a pertinent contribution to California stratigraphy in this article and has presented data on topics which for many years have not been adequately treated.

G. Dallas Hanna and Leo George Hertlein discuss and illustrate some common and characteristic pre-Cretaceous, Cretaceous, and Tertiary fossils whose stratigraphic ranges are restricted. Accompanying the paper are 6 plates of megafossils, one plate of diatoms,

[1,2] Department of geology, Colorado School of Mines. Review received, September 17, 1943.

and one plate of Foraminifera. This work is incomplete, as the authors state, but will undoubtedly be of service for general correlations.

Frank M. Anderson presents a "Synopsis of the Later Mesozoic in California" and Bruce L. Clark contributes "Notes on California Tertiary Correlation." Boris V. Laiming considers the Eocene problem of California and presents columnar sections with correlations based on the Foraminifera. He also gives a chart showing the distribution of charateristic Eocene foraminiferal assemblages. Lesh C. Forrest offers a correlation of Oligocene strata; Robert M. Kleinpell presents his views on Miocene correlation; U. S. Grant IV and Leo George Hertlein give a correlation chart representing the relative ages of some of the Pliocene stratigraphic units commonly used by California geologists; and J. E. Eaton discourses on the sedimentation and the geologic history of the region during the Pleistocene.

Stanley G. Wissler gives the results of his micropaleontologic studies of the Los Angeles Basin during the past 15 years. His data include an excellent discussion of the foraminiferal zonation of the Basin stratigraphy. Stratigraphic variation charts and zonal charts accompany the article. Stanley G. Wissler and Frank E. Dreyer present a discussion on the correlation of the oil fields of the Santa Maria district. Glen C. Ferguson covers the correlation of the oil field formations on the east side of San Joaquin Valley while Paul P. Goudkoff contributes to the correlation of the stratigraphic sequence on the west side of the Valley.

The final paper of part two involves an excellent discussion of the origin, migration, and accumulation of oil in California by Harold W. Hoots. He reviews the various theories about this subject, and considers types of traps, reservoirs, and probable source rocks of California.

Parts 3 and 4 are bound together in the preprint edition. Part 3, "Description of Individual Oil and Gas Fields," comprising Chapters VIII to XIII, pages 277 to 664, is by 99 authors. It is profusely illustrated by 167 text figures many of them representing structure-contour maps. Concise descriptions by districts of most of the individual oil and gas fields and prospective areas of California, each prepared by one or more recognized authorities, are included. In the few instances where contributors for significant areas could not be found the reader may consult published works cited among the references in Parts 3 and 4. An attempt was made to have the important facts regarding each area presented in a uniform pattern so far as local conditions would permit. The following topics are stressed: history, significance, distinguishing features, stratigraphy, structure, productive horizons, kind of oil and gas, and selected references. The location of each field is shown on a key map. Though the descriptions are brief, the data may be supplemented from the literature cited.

In the case of the older areas the information is brought up to date both in the descriptive text and in the maps and sections.

Inasmuch as the individual contributions were received over a period of nearly 4 years the subject matter on certain areas has been supplemented by later investigations. A list of important recent articles is given in the preface.

The final chapter of Part 3 presents, in tabulated form by counties, data on more than 1,000 wells drilled in California outside of the principal oil and gas fields. The location, name of company and well, time of drilling, depth in feet, and formation at the bottom of the hole are given.

Part 4 which bears the title, "Glossaries, Bibliography, and Index," includes Chapters XIV to XVI, pages 665 to 773. Chapter XIV comprises a "Glossary of the Geologic Units of California," abstracted and revised by Olaf P. Jenkins from the work of Alice S. Allen and *Bulletins 769, 826*, and *896* of the United States Geological Survey, prepared by M. Grace Wilmarth.

Chapter XV, "Bibliography," by Elisabeth L. Egenhoff, contains a list of publications cited throughout *Bulletin 118*. The final chapter (XVI), also by Elisabeth L. Egenhoff, is devoted to a comprehensive index of the subject matter of the report.

Since California has attained foremost rank in oil production, being second only to Texas in cumulative yield to date, the appearance of this report is very timely. It is a valuable reference work to those interested purely in the geology of the region as well as to those directly interested in the oil and gas resources of the Pacific Border Province and in the problems of the origin, migration, and accumulation of the natural hydrocarbons. The coöperation of leading students of California geology in the enterprise renders the report highly meritorious. While there is a lack of continuity and coördination in some sections, as must be anticipated in a compendium organized along such lines, it is felt that this is overshadowed by the weight of authority gained by the style of attack followed. The State of California and the Division of Mines are to be congratulated upon the thoroughness and high quality of this splendid report. Taken in conjunction with the revised geologic map of California issued by the Division of Mines in 1938, it represents one of the most important reference works in geology that has appeared in recent years.

RECENT PUBLICATIONS

BOLIVIA

*"Bibliographía Geológica de Bolivia," by Victor Oppenheim. *Bol. Soc. Geogr. La Paz*, Vol. 53, No. 65 (La Paz, 1943). 19 pp.

COLOMBIA

*"Geología de la Cordillera Oriental entre los Llanos y el Magdalena," by Victor Oppenheim. Reprint from *Revista Acad. Colombiana de Ciencias Exactas, Fisico-Quimicas y Naturales*, Vol. 4, No. 14 (Bogota, 1941), pp. 75–81; sketch map of Colombia, and 3 pls. in colors.

*"Geología del Departmento del Magdalena," *ibid.*, Nos. 15–16 (December, 1941), pp. 380–84; 12 photographs, geological map in colors.

*"Rasgos Geológicos de los 'Lanos' de Colombia Oriental," by Victor Oppenheim. Reprint from *Notas Museo La Plata*, Tomo 7, Geol. No. 21 (Inst. Museo Univ. Nac. La Plata, La Plata, Argentina, 1942), pp. 229–46, sketch map of Colombia with cross section.

GENERAL

*"Oil Zones of the United States: Upper Cretaceous," compiled by *Oil and Gas Jour.*, Vol. 42, No. 17 (Tulsa, September 2, 1943), p. 36 B; map in colors.

*"Application of Geology to the Principles of War," by Charles E. Erdmann. *Bull. Geol. Soc. America*, Vol. 54, No. 8 (New York, August 1, 1943), pp. 1169–94.

*"Bibliography on the Interpretation of Aerial Photographs and Recent Bibliographies on Aerial Photography and Related Subjects," by Genevieve C. Cobb. *Ibid.*, pp. 1195–1210.

*"Petroleum Industry Has Entered a New Phase," by Benjamin T. Brooks. *Oil Weekly*, Vol. 110, No. 12 (Houston, August 23, 1943), pp. 12–17; 5 tables.

*"Ozarkian and Canadian Cephalopods. Pt. II: Brevicones," by E. O. Ulrich, Aug. F. Foerste, and A. K. Miller. *Geol. Soc. America Spec. Paper 49* (New York, August 14, 1943). 240 pp., 70 pls., 15 text figs., 1 table.

"Geology and Biology of North Atlantic Deep-Sea Cores between Newfoundland and Ireland," by W. H. Bradley *et al. U. S. Geol. Survey Prof. Paper 196* (July, 1943). 163 pp., 23 pls., 30 figs. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $1.25.

"Lower Pennsylvanian Species of Mariopteris, Eremopteris, Diplothmema, and Aneimites from the Appalachian Region," by David White (a posthumous work); assembled and edited by C. B. Read. *Ibid., Prof. Paper 197-C* (July, 1943), pp. 85–140; Pls. 8–39. Price, $0.20.

ITALY

*"Italian Oil Fields Small but Important to Axis," *Anon.* Based on information from J. Elmer Thomas. *Oil Weekly*, Vol. 110, No. 12 (Houston, August 23, 1943), pp. 10–11; 3 photographs.

MONTANA

*"Structure of Central Part of Sawtooth Range, Montana," by Charles Deiss. *Bull. Geol. Soc. America*, Vol. 54, No. 8 (New York, August 1, 1943), pp. 1123–68; 9 pls., 6 figs.

PENNSYLVANIA

*"Ordovician Clastic Sedimentary Rocks in Pennsylvania," by Bradford Willard. *Bull. Geol. Soc. America*, Vol. 54, No. 8 (New York, August 1, 1943), pp. 1067–1122; 11 pls., 8 figs.

SOUTH AMERICA

*"Bibliography of Economic Geology of South America," by Joseph T. Singewald, Jr., *Geol. Soc. America Spec. Paper 50* (New York, August 30, 1943). 159 pp.

TEXAS

*"Oil and Gas Fields of Jackson County, Texas," by J. Brian Eby. *Oil Weekly*, Vol. III, No. 4 (Houston, September 27, 1943), pp. 20–26; 5 figs., map, 2 tables.

*"Geology of Central Jackson County, Texas, Oil Fields," by Joseph Hornberger, Jr. *Oil Weekly*, Vol. III, No. 5 (October 4, 1943), pp. 18–24; 5 figs.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

Journal of Paleontology (Tulsa, Oklahoma), Volume 17, No. 5 (September, 1943).

"Spiriferacea of the Cedar Valley Limestone of Iowa," by Merrill A. Stainbrook

"Lower Cretaceous Crinoids from Texas," by Raymond E. Peck.

"Foraminifera from the Duck Creek Formation of Oklahoma and Texas," by Helen Tappan

"Additions to the Fauna of the Trent Marl of North Carolina," by Horace G. Richards

"Upper Jurassic Ammonites from the Placer de Guadalupe. Chihuahua, Mexico," by Ralph W. Imlay

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 10 (OCTOBER, 1943), PP. 1397-1398

THE ASSOCIATION ROUND TABLE

ASSOCIATION COMMITTEES

The list of Association Committees, with the names of the chairmen and the members, is published in the June *Bulletin*, pages 876–78.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Leland Wayne Ashmore, Midland, Texas
Fred H. Wilcox, Taylor Cole, George R. Gibson
Thomas Judson Bevan, Dallas, Texas
S. A. Thompson, Paul E. Nash, J. J. Simkins
Gerard Lakin Browne, Suitland, Maryland
Malvin G. Hoffman, George L. Ellis, Nicholas G. Dumbros
William Henry Craig, Olney, Texas
Dan D. Heninger, Donald Kelly, J. J. Russell, Jr.
Frank B. Kelsey, Canoga Park, California
Herschel L. Driver, W. S. W. Kew, R. G. Reese
F. Stearns MacNeil, Washington, D. C.
Watson H. Monroe, John B. Reeside, Jr., L. W. Stephenson
John Harper Melvin, Crafton, Pennsylvania
A. C. Trowbridge, R. B. Senseman, L. C. Glenn
William Mitchell Peden, Great Falls, Montana
J. E. Hupp, J. H. McCourt, C. E. Dobbin
James Edward Walker, Houston, Texas
F. Goldstone, Thomas L. Bailey, L. G. Christie

FOR ASSOCIATE MEMBERSHIP

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Stanley W. Wilcox, G. H. Westby, G. M. Giltinan
George Wagner Dimock, Wichita Falls, Texas
Earl M. Stilley, Dan D. Heninger, W. C. Bean
Robert Louis Gollnick, Houston, Texas
Frank W. DeWolf, Harold R. Wanless, Gerald Albert Northrip
Joseph J. Graham, Taft, California
Burton R. Ellison, E. C. Doell, W. F. Barbat
Carl Wilburn Hemmi, San Antonio, Texas
P. J. Rudolph, O. S. Petty, F. L. Whitney
Donald Grant Herring, Jr., Shreveport, Louisiana
R. F. Baker, W. T. Thom, Jr., G. W. Schneider
Rolfe Sherman Johnson, Fort Worth, Texas
Harold W. Hoots, Elmo W. Adams, Harry Johnson

Arthur Joseph Mestier, Jr., Cambridge, Massachusetts
W. L. Whitehead, Roland F. Beers, Alfred Senn
John Man Morgan, Houston, Texas
R. L. Beckelhymer, C. H. Sample, C. M. Langton
Stewart Colin Palmerston, Tulsa, Oklahoma
John W. Daly, Barthold W. Sorge, Cecil E. Reel
Charles Wilcox Sheppard, Cambridge, Massachusetts
W. L. Whitehead, Roland F. Beers, Edward L. Tullis
Robert Hudson Tennant, Midland, Texas
Willard F. Bailey, James Fitzgerald, Jr., Joseph E. Morero
James Neff Wilson, Tulsa, Oklahoma
H. C. Becker, Stanley W. Wilcox, J. L. Gartner
Keith Preston Young, Buffalo, Wyoming
W. H. Twenhofel, W. T. Thom, Jr., Horace D. Thomas

FOR TRANSFER TO ACTIVE MEMBERSHIP

Pierre Bayle, Houston, Texas
E. G. Leonardon, P. Charrin, J. Brian Eby
Jay Miles Frost, III, Houston, Texas
John C. Miller, Robert H. Cuyler, R. H. Goodrich
Albert Lee Jones, Corpus Christi, Texas
G. B. Gierhart, Ira H. Stein, H. D. McCallum
Charles H. Rankin, Jr., Wichita Falls, Texas
Edgar W. Kimball, P. M. Martin, Victor G. Hendrickson
Robert Crim Redfield, Austin, Texas
F. B. Plummer, E. H. Sellards, Hal P. Bybee

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 10 (OCTOBER, 1943), PP. 1399-1401, 1 FIG.

Memorial

LOUIS SAMUEL PANYITY

(1890–1943)

Louis Samuel Panyity, a member of the American Association of Petroleum Geologists from 1920 to 1933, died at Bradford, Pennsylvania, on July 29, 1943. He had been in poor health for 3 years, but, in spite of this, he continued active and was in his office and laboratory almost daily until a few days before his death.

LOUIS SAMUEL PANYITY

Louis Samuel Panyity was born in Budapest, Hungary, August 7, 1890, and came to the United States with his parents at the age of 12. He was an only child. His father, who settled in New York, was an engineer and inventor. Louis attended the Reformed Gymnasium of Budapest, the New York High School of Commerce, and the University of Pittsburgh, graduating from the last institution in 1915 with the degree of Bachelor of Science in Petroleum Engineering. He was a member of the first class to graduate from Roswell H. Johnson's original course in petroleum engineering. At the University, Louis

was a member of the Cap and Gown Club, played Varsity basket ball and won his letter on the track team. During his last year in college, he held a part-time instructorship in surveying and did some engineering and geological work for the Fayette County Gas Company.

Upon graduation in 1915, he accepted employment as a geologist with the Ohio Fuel Supply Company and other subsidiaries of the Columbia Gas and Electric System at Columbus, Ohio. He advanced rapidly to the position of chief geologist. In 1922 he resigned to accept a position as oil and gas valuation engineer in the newly created Oil and Gas Section of the Natural Resource Division of the Bureau of Internal Revenue. He was assigned the task of making a study of the Bradford oil field. The rejuvenation of this old field by water-flooding was presenting the Bureau of Internal Revenue with some unique problems at the time. On completion of the Bradford assignment in 1923, he resigned to enter the consulting field. He established an office and later a laboratory at Bradford, which he maintained until the time of his death. Many of the prominent oil producers of the district became his clients. Their interests extended over most of the oil-producing areas of the United States so that his consulting practice included work not only throughout the Appalachian region but also in the oil fields of Indiana, Illinois, Michigan, Kansas, Oklahoma, Texas, and Wyoming.

In his course in petroleum geology, Roswell H. Johnson early emphasized the importance of a fuller consideration of the shape and texture of the reservoir rather than mere mapping of structure. "Pan" was guided by this precept. While serving as geologist with the Ohio Fuel Supply Company, he prepared papers on the "Southern Extremity of the 'Clinton' Gas Pools in Ohio," "Lithology of the Berea Sand in Southeastern Ohio and Its Effect on Production," "Natural Gas Storage," and "Oil and Gas Bearing Horizons of the Ordovician System in Ohio," which were published in the *Transactions* of the American Institute of Mining and Metallurgical Engineers and the *Bulletin* of the American Association of Petroleum Geologists. During this period, he also wrote a book, *Prospecting for Oil and Gas*, which was published by John Wiley and Sons in 1920.

In connection with his study of the Bradford oil field for the Bureau of Internal Revenue, he made the first structure map of that field. This map is included in the paper on the Bradford oil field, of which he was a co-author, which appears in Volume 2 of *Structure of Typical American Oil Fields*.

In some respects, "Pan" was one of the pioneers in petroleum geology and engineering. In 1924, he supervised the taking of the diamond-drill core of the Bradford Third sand from which A. F. Melcher obtained the samples that enabled him to construct, for the first time, a porosity profile of an oil sand. Later he introduced a method of "chip-sampling" of oil sands with a standard cable-tool bit, which has been extensively used in the Bradford field in recent years. He early recognized the value of core analysis and set up a laboratory at Bradford in conjunction with his office. He was one of the group who in the 1920's closely studied oil sands, established the concepts of porosity and permeability, and laid the foundations of modern core analyses. He probably contributed less than some others to the theoretical and laboratory work on these problems, but did much to advance their practical applications to oil-field development. Two papers, one on the "Practical Interpretation of Core Analyses," and the other on "Valuation of Properties in the Bradford District," published in the *Transactions* of the American Institute of Mining and Metallurgical Engineers, were based on observations made and work done during this period. "Pan" found time to prepare occasional technical articles for the *Oil and Gas Journal* and popular articles relating to the petroleum industry for *Colliers* and *Leslies' Magazine*.

"Pan" was gifted with a dry and delightful sense of humor which never failed him. He was exceedingly generous in exchanging information, which was not confidential,

with others engaged on similar problems. Those of us who had occasion to visit Bradford from time to time will miss him.

He married Helen Marie Stephens of Pittsburgh, Pennsylvania, on June 24, 1916. Surviving are his widow, a son, Aviation Cadet Glenn Stephens Panyity, and a daughter, Helen Patricia Panyity.

CHARLES R. FETTKE[1]

PITTSBURGH, PENNSYLVANIA
September 8, 1943

[1] Grateful thanks are extended for the assistance rendered by Parke A. Dickey and Paul Phillippi in furnishing a considerable part of the information for this memorial.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

H. A. IRELAND, recently associate geologist in the Climatic and Physiographic Research Division of the Soil Conservation Service of the United States Department of Agriculture, is now geologist in the Fuel Section of the Geological Survey of the United States Department of the Interior. He has office space with the Oklahoma Geological Survey at Norman, Oklahoma.

HUGH D. MISER, of the United States Geological Survey, Washington, D. C., discussed "The Program of Oil and Gas Work by the United States Geological Survey," at a meeting of the Tulsa Geological Society, September 13.

ROSS ALLEN MAXWELL, geologist with the National Park Service, has been appointed superintendent of the Big Bend National Park, Texas.

The Fort Worth Geological Society has arranged to hold its meetings jointly with Petroleum Engineers Club of Fort Worth, at the Texas Hotel on Wednesdays, approximately bi-weekly. The two groups will alternate in furnishing speakers. This combination of meetings helps meet hotel difficulties in serving small luncheon and dinner groups during the period of shortage of food ration points. The meeting dates are October 20, November 3 and 10, December 1 and 15, January 5 and 19, and February 2 and 16.

SAMUEL W. WELLS, 520 Citizens National Bank Building, Evansville, Indiana, is manager of exploration for the Ashland Oil and Refining Company of Ashland, Kentucky.

FRANK THOMAS WHITTINGHILL, JR., recently head of the geological department of Bell Brothers, Robinson, Illinois, has entered the Navy as an ensign.

HAROLD H. HAWKINS, previously in the National Park Service, is in the Army, doing geological work. His permanent address is 1011 Cleveland Avenue, Kansas City, Kansas.

W. E. BELT, JR., is junior geologist with the United States Geological Survey, temporarily stationed at Oxford, Mississippi.

ALBERT GREGERSEN, recently with The Texas Company, is district geologist for District No. 5 of the Petroleum Administration for War, Los Angeles, California.

NORMAN S. HINCHEY, formerly with the Shell Oil Company, Inc., is assistant professor of geology at Washington University, St. Louis, Missouri.

ROLAND F. HODDER, formerly with the Lone Star Steel Corporation, is geological scout with the Stanolind Oil and Gas Company at Houston, Texas.

J. W. HOOVER is superintendent of the geophysical department of The California Company at New Orleans, Louisiana.

LEMOYNE W. MYERS is a petroleum engineer with the Phillips Petroleum Company, Bartlesville, Oklahoma.

EDMOND G. OTTON has been transferred from the Bureau of Standards at Washington,

D. C., to the Ground Water Division of the United States Geological Survey at Raleigh, North Carolina.

T. PRESTON WARE, JR., is geologist with the Circle Oil Company, Houston, Texas.

J. BRIAN EBY presented his paper, "The Oil and Gas Fields of Jackson, County, Texas," before the Houston Geological Society, September 16. An interesting discussion followed. Approximately 100 members were present.

Lieutenant Colonel OLIN G. BELL, formerly geologist with the Humble Oil and Refining Company, Houston, Texas, is base executive officer of Peterson Army Air Field, Green Mountain Falls, Colorado.

N. C. DAVIES, consulting geologist, Mount Vernon, Illinois, has been appointed chief geologist for Bell Brothers, at Robinson, Illinois.

BENJAMIN F. PILCHER, geologist for The Texas Company at Fort Worth, has been transferred to Midland, Texas, as district geologist.

L. C. THOMAS, formerly district geologist for The Texas Company at Midland, Texas, has resigned to enter consulting practice.

CHANNING G. SCHWARTZ, geologist with the Carter Oil Company at Shreveport, Louisiana, has been moved to Magnolia, Arkansas, as district geologist.

New officers of the Oklahoma City Geological Society are: president, I. CURTIS HICKS, Phillips Petroleum Company; vice-president, E. G. DAHLGREN, Interstate Compact Commission; secretary-treasurer, THEODORE G. GLASS, Sinclair Prairie Oil Company.

VICTOR P. GRAGE, who has been associated with the H. L. Hunt Companies of Dallas, Texas, in the capacity of chief geologist, resigned effective September 1, in order to open an office as consulting geologist, located in Room 413, Ardis Building, Shreveport, Louisiana.

J. B. REESIDE, JR., of the United States Geological Survey, talked on "The Upper Cretaceous of the Western Interior of the United States," before the Houston Geological Society, September 20.

EZEQUIEL ORDOÑEZ, of Mexico City, has published a description of the recent volcanic eruption in Mexico, entitled *El Volcan de Paricutin*, a booklet of 15 pages, with 10 photographs, printed in Spanish.

L. M. CLARK, formerly division geologist for the Shell Oil Company at Centralia, Illinois, has been transferred to Calgary, Alberta, as chief geologist for the Shell Oil Company of Canada Limited. His address is the Bank of Toronto Building, Calgary, Alberta.

JOSEPH T. SINGEWALD, JR., head of the department of geology, Johns Hopkins University, Baltimore, has been appointed director of the State of Maryland Department of Geology, Mines, and Water Resources, succeeding EDWARD B. MATHEWS.

JOHN GALLOWAY, of Calgary, has been appointed president of the Dominion Oil Company, operating in the Tabor field of southern Alberta, Canada.

OSCAR HATCHER has resigned his position with the Mid-Continent Petroleum Corporation, to become chief geologist for Helmerich and Payne, Inc., Tulsa, Oklahoma.

REGINALD G. RYAN is employed by Northern Ordnance, Inc., with headquarters at 1603 Philtower, Tulsa, Oklahoma.

CONSTANCE LEATHEROCK, formerly with the Tide-Water Associated Oil Company at Tulsa, Oklahoma, is associate geologist with the United States Geological Survey, stationed at Lawrence, Kansas.

Captain WILLIAM M. NICHOLLS, of San Antonio, Texas, wrote in September that he was "enroute somewhere in China."

NORVAL W. NICHOLS, recently with the Superior Oil Company of New Zealand, is with the Superior Oil Company at Calgary, Alberta, Canada.

GLEN M. RUBY, of the United Geophysical Company, Inc., has working with him in Chile the following geologists: JOSEPH S. HOLLISTER, HARVE LOOMIS, C. L. MOHR, EVERETT S. SHAW, and KARL L. WALTER. Their company headquarters address is Casilla 600, Punta Arenas, Chile.

New officers of the Shreveport Geological Society, Shreveport, Louisiana, are: president, W. H. SPEARS, Union Producing Company, Drawer 1407; vice-president, T. H. PHILPOTT, Carter Oil Company, Drawer 1739; secretary-treasurer, E. P. OGIER, c/o W. C. SPOONER, consulting geologist, Box 1195.

BEN H. PARKER, of the Colorado School of Mines, Golden, Colorado, has been elected vice-president in charge of geology and land work of the Frontier Refining Company.

JAMES FITZGERALD, JR., who has been division manager of the land and lease department of the Skelly Oil Company at Midland, Texas, for several years, has resigned to open a consulting and operating office. H. WINSTON HULL, has been transferred from Tulsa to Midland, succeeding Fitzgerald.

CECIL V. HAGEN received his Navy "wings" at the Flight Instructors School at New Orleans in June and is now on duty as flight instructor at the United States Naval Air Station, Dallas, Texas.

The East Texas Geological Society, Tyler, Texas, has elected the following new officers: president, G. J. LOETTERLE, Shell Oil Company; vice-president, B. W. ALLEN, Gulf Oil Corporation; secretary-treasurer, L. L. HARDEN, Sinclair Prairie Oil Company; and member of the executive committee, J. H. MCGUIRT, Magnolia Petroleum Corporation.

W. TAYLOR THOM, JR., of Princeton University, spoke on "The Structural Evolution of the Big Horn Basin Region," before the Shreveport Geological Society, October 7.

ROBERT L. BREEDLOVE has moved from San Antonio, Texas, to Shreveport, Louisiana, where he is evaluation geologist for the Arkansas Natural Gas Corporation.

JOSEPH D. WATSON is temporarily connected with the United States Army Engineers at Tulsa, Oklahoma.

PARKER D. TRASK, of the United States Geological Survey, spoke before the Pacific Section of the Association, at Los Angeles, California, September 10, on the Mexican volcano, Paricutin.

DONALD L. NORLING, of the Shell Oil Company, Inc., has been transferred from Tulsa, Oklahoma, to Centralia, Illinois.

RALPH W. IMLAY, of the United States Geological Survey, presented his paper, "The Jurassic Formations of the Gulf Region," before the Tulsa Geological Society, October 4.

The Houston Geological Society presented the following program, September 30: J. ELMER THOMAS, "Moving Pictures of the Italian Oil Fields and the Geology and Geography of Parts of Southern Italy"; and JOSEPH HORNBERGER, JR., "Geology of the Oil Fields of Central Jackson County, Texas."

P. J. DAWSON recently left the production division of the Petroleum Administration for War, to join Glenn H. McCarthy, Inc., as engineer.

D. B. EICHER, formerly with the Dominican Seaboard Oil Company, is with the Standard Oil Company of Egypt, Cairo.

CHARLES E. FRALICH is president of the Appalachian Development Corporation, Bradford, Pennsylvania.

RUDOLF MARTIN, of the Caribbean Petroleum Company, has been transferred from Maracaibo to Caracas, Venezuela, where his work is to be field geology.

GUY E. MILLER, of the Shell Oil Company, Inc., has changed his address from Bakersfield, California, to 226 Fratt Building, Billings, Montana.

Captain HOWARD C. PYLE is in the Fuels and Lubricants Division of the Office of the Quartermaster General, Washington, D.C.

Captain HERBERT E. WILLIAMS is at the Adjutant General's School, Fort Washington, Maryland.

M. M. FIDLAR, formerly district geologist for the Ohio Oil Company at Bloomington. Indiana, is senior geologist for the Mountain Fuel Supply Company, Rock Springs, Wyoming.

Captain PERRY S. MCCLURE may be addressed: APO No. 402, c/o Postmaster, Nashville, Tennessee.

A symposium on oil-field waters and oil-field brine disposal is being planned to take the form of a joint meeting of the Houston, East Texas, Austin, and College Station sections of the A.I.M.E. to be held at the Stephen F. Austin Hotel, in Austin, in connection with the annual fall meeting of the Texas Academy of Science, November 12. The following members of the Institute will take part in the program: CHARLES WARNER, chairman, Petroleum Section, Houston Oil Company; W. S. MORRIS and L. H. DIAL, East Texas Salt Water Association; F. W. JESSEN and F. W. ROLSHAUSEN, Humble Oil and Refining Company; PAUL WEAVER, Gulf Oil Corporation; W. N. WHITE, United States Geological Survey; F. M. BULLARD, FRED BARCLAY, and HARRY H. POWER, University of Texas; I. W. ALCORN, Pure Oil Company; R. W. ERWIN, Salt Water Control, Inc.; and J. M. BUGBEE, National Lead Company. F. B. PLUMMER, of the University of Texas, is chairman of the program committee. In addition, it is planned to have a noon luncheon with an illustrated lecture by FRED M. BULLARD on the new active volcano in Mexico, and a smoker in the evening with appropriate entertainment. Many will stay over for the T.C.U. football game the following day, November 13.

MAX STEINEKE has left the Standard Oil Company of British Columbia, Calgary, Canada, to join the California Arabian Standard Oil Company, Bahrein Island, Persian Gulf. His address is APO 816, c/o Postmaster, New York, New York.

PEDRO JOAQUIN BÉRMUDEZ has been transferred from the Dominican Seaboard Oil Company to the Standard Oil Company of Cuba at Habana.

A. E. FELDMEYER, recently with the Superior Oil Company of New Zealand, Ltd., may be addressed at Box 367, Calgary, Alberta, Canada.

J. B. REESIDE, JR., of the United States Geological Survey, discussed the Cretaceous before the Shreveport Geological Society, September 28.

LAURENCE N. DEXTER is party chief with the National Geophysical Company at Three Rivers, Texas.

C. W. CONNELLY, of the Ohio Oil Company, has moved from Marshall, Illinois, to Owensboro, Kentucky.

W. C. GIBSON, JR., is with the British-American Oil Producing Company at Wichita Falls, Texas.

H. C. MCCARVER, of Geophysical Service, Inc., has moved from Bakersfield, California, to Smithville, Texas.

DWIGHT C. ROBERTS, recently at Houston, Texas, has moved to Los Angeles, California. He is with the Sperry-Sun Well Surveying Company.

CHARLES F. ALLEN is with the Western Geophysical Company at Modesto, California.

H. E. DANA is engaged in research geophysics with the Independent Exploration Company, Houston, Texas.

GEORGE H. CLARK, of The Texas Company, formerly at New Orleans, Louisiana, is now at Houston, Texas.

CECIL DRAKE, of the Shell Oil Company, Inc., formerly at Centralia, Illinois, is located at Tulsa, Oklahoma.

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CALIFORNIA

COLORADO

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

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The California Company
1st Vice-President - - - - - C. E. Erdmann
U. S. Geological Survey
2nd Vice-President - - - - - John E. Blixt
The Texas Company
Secretary-Treasurer - - - - Gaylord Frazier
U. S. Geological Survey, 208 Custom House

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Cosmopolitan Hotel.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - - Richard S. Hicklin
Carter Oil Company

Vice-President - - - - - - - Charles J. Hoke
Phillips Petroleum Company

Secretary-Treasurer - - - - Robert F. Eberle
The Superior Oil Company

Meetings will be announced.

LOUISIANA

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NEW ORLEANS, LOUISIANA

President - - - - - - - - - - J. W. Hoover
The California Co., 1818 Canal Bldg.
Vice-President - - - - - - - - H. C. Petersen
Freeport Sulphur Co., American Bank Bldg.
Secretary-Treasurer - - - - - W. J. Gillingham
Schlumberger Well Surveying Corporation
452 Canal Bldg.

Meets the first Monday of every month, 7:30 P.M., St. Charles Hotel. Special meetings by announcement.

LOUISIANA

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LAKE CHARLES, LOUISIANA

President - - - - - - - - - H. E. McGlasson
Stanolind Oil and Gas Company
Vice-President - - - - - - - - - C. B. Roach
Shell Oil Company, Inc.
Secretary - - - - - - - - - - A. L. Morrow
Magnolia Petroleum Company
Treasurer - - - - - - - - - D. N. Rockwood
Union Producing Company

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - Darsie A. Green
The Pure Oil Company, Box 311, Olney

Vice-President - - - - - - - Clark T. Snider
Lario Oil and Gas Company, Mt. Vernon

Secretary-Treasurer - - - - - Fred H. Moore
Magnolia Petroleum Corp., Box 535, Mt. Vernon

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - - - E. P. Philbrick
Magnolia Petroleum Company
Vice-President - - - - - - - Jack M. Copass
Amerada Petroleum Corp., Box 995
Secretary-Treasurer - - - Robert B. McNeely
209 Ellis-Singleton Building
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - - - W. H. Spears
Union Producing Company, Drawer 1407
Vice-President - - - - - - - - T. H. Philpott
Carter Oil Company, Drawer 1739
Secretary-Treasurer - - - - - - E. P. Ogier
c/o W. C. Spooner, Box 1195

Meets the first Monday of every month, September to May, inclusive, 7:30 P.M., Criminal Courts Room, Caddo Parish Court House. Special meetings and dinner meetings by announcement.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - George D. Lindberg
Sun Oil Company, Toledo, Ohio
Vice-President - - - - Edward J. Baltrusaitis
Gulf Refining Company, Box 811, Saginaw
Secretary-Treasurer - - - - Mrs. Lucille Esch
State Geological Survey, Lansing
Business Manager - - - - - William Schulz
Cities Service Oil Co., Mt. Pleasant

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - David C. Harrell
Carter Oil Company, Box 1490

Vice-President - - - - - - - L. R. McFarland
Magnolia Petroleum Company
508 Millsaps Building

Secretary-Treasurer - - - - - K. K. Spooner
The Atlantic Refining Company, Box 2407

Meetings: First and third Wednesdays of each month from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - - C. C. Hannum
The Texas Company

Vice-President - - - - - - - - J. P. Gill
Sinclair Prairie Oil Company

Secretary-Treasurer - - - - J. M. Westheimer
Samedan Oil Corporation, Box 959

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - - I. Curtis Hicks
Phillips Petroleum Company
1211 First National Building

Vice-President - - - - - - - E. G. Dahlgren
Interstate Oil Compact Commission
State Capitol

Secretary-Treasurer - - - - Theodore G. Glass
Sinclair Prairie Oil Company
703 Colcord Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon, Skirvin Hotel Coffee Shop.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

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Stanolind Oil and Gas Company

Vice-President - - - - - Edwin A. Dawson
1829 N. Broadway

Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

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TULSA, OKLAHOMA

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Consulting Geologist, 301 Beacon Building

1st Vice-President - - - - - - - J. V. Howell
912 Philtower

2nd Vice-President - - - - - - - Jerry E. Upp
Amerada Petroleum Corporation

Secretary-Treasurer - - - - - - James A. Price
W. C. McBride, Inc., 625 Wright Bldg.

Editor - - - - - - - - - - Roy L. Ginter
Ginter Laboratory

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Bradford Hotel.

TEXAS

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CORPUS CHRISTI, TEXAS

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Consulting, Nixon Building

Vice-President - - - - - - - - E. D. Pressler
Humble Oil and Refining Company, Box 1271

Secretary-Treasurer - - - John Bruce Scrafford
Consulting, Driscoll Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

President - - - - - - - S. A. Thompson
Magnolia Petroleum Co., P. O. Box 900

Vice-President - - - - - Joseph M. Wilson
Continental Building

Secretary-Treasurer - - - - - Robert I. Seale
Schlumberger Well Surveying Corporation
1004 Continental Building

Executive Committee - - - - - T. K. Knox
Republic Natural Gas Co., Houseman Bldg.

Meetings: Regular luncheons, first Monday of each month, 12:00 noon, Petroleum Club, Adolphus Hotel. Special night meetings by announcement.

TEXAS

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Shell Oil Company, Inc., Box 2037

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Gulf Oil Corporation

Secretary-Treasurer - - - - - - L. L. Harden
Sinclair Prairie Oil Company, Box 1100

Executive Committee - - - - J. H. McGuirt
Magnolia Oil Company

Meetings: Monthly and by call.
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel.

FORT WORTH GEOLOGICAL SOCIETY

FORT WORTH, TEXAS

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The Pure Oil Company, Box 2107

Vice-President - - - - William J. Hilseweck
Gulf Oil Corporation

Secretary-Treasurer - - - Richard H. Schweers
The Texas Company, Box 1720

Meetings: Luncheon at noon, Texas Hotel, first and third Wednesdays of each month, jointly with Petroleum Engineers Club. Visiting geologists welcome.

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Houston Natural Gas Corp., Box 1188

Treasurer - - - - - - - William F. Calohan
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Regular meeting held the first and third Thursdays at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

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Vice-President - - - - - - - Dolph E. Simic
Cities Service Oil Co.

Secretary-Treasurer - - - Carlos M. Ferguson
Magnolia Petroleum Co., 500 Waggoner Bldg.

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY

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Consulting, 2101 Alamo National Building

Vice-President - - - - - - Harvey Whitaker
Consulting, 1409 Milam Building

Secretary-Treasurer - - - - Arthur H. Petsch
The Ohio Oil Co., 1417 Milam Building

Meetings: Third Tuesday of each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST TEXAS GEOLOGICAL SOCIETY

MIDLAND, TEXAS

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Magnolia Petroleum Company

Vice-President - - - - - - Prentiss D. Moore
Moore Exploration Company

Secretary-Treasurer - - - - - - Dana M. Secor
Atlantic Refining Company

Meetings will be announced

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CHARLESTON, WEST VIRGINIA
P. O. Box 2385

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Godfrey L. Cabot, Inc., Box 1473

Vice-President - - - - - - - - H. J. Wagner
Public Service Commission

Secretary-Treasurer - - - - - Cramon Stanton
United Carbon Company, Box 1913

Editor - - - - - - - - - - Robert C. Lafferty
In Service (Navy)

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

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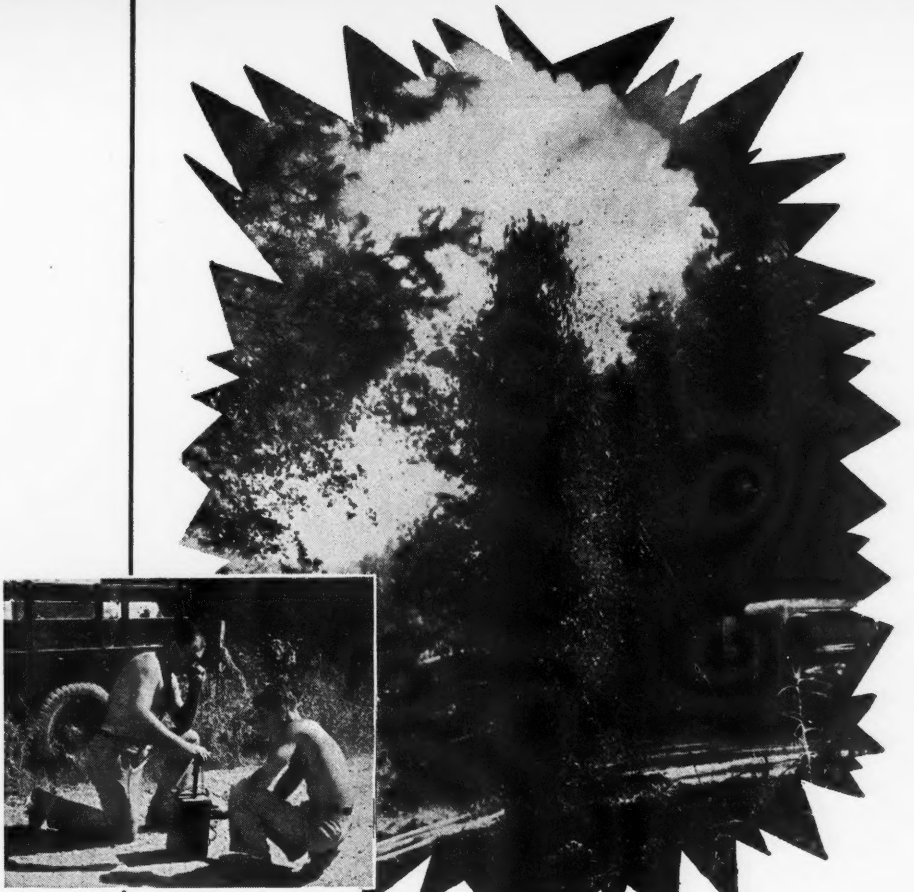
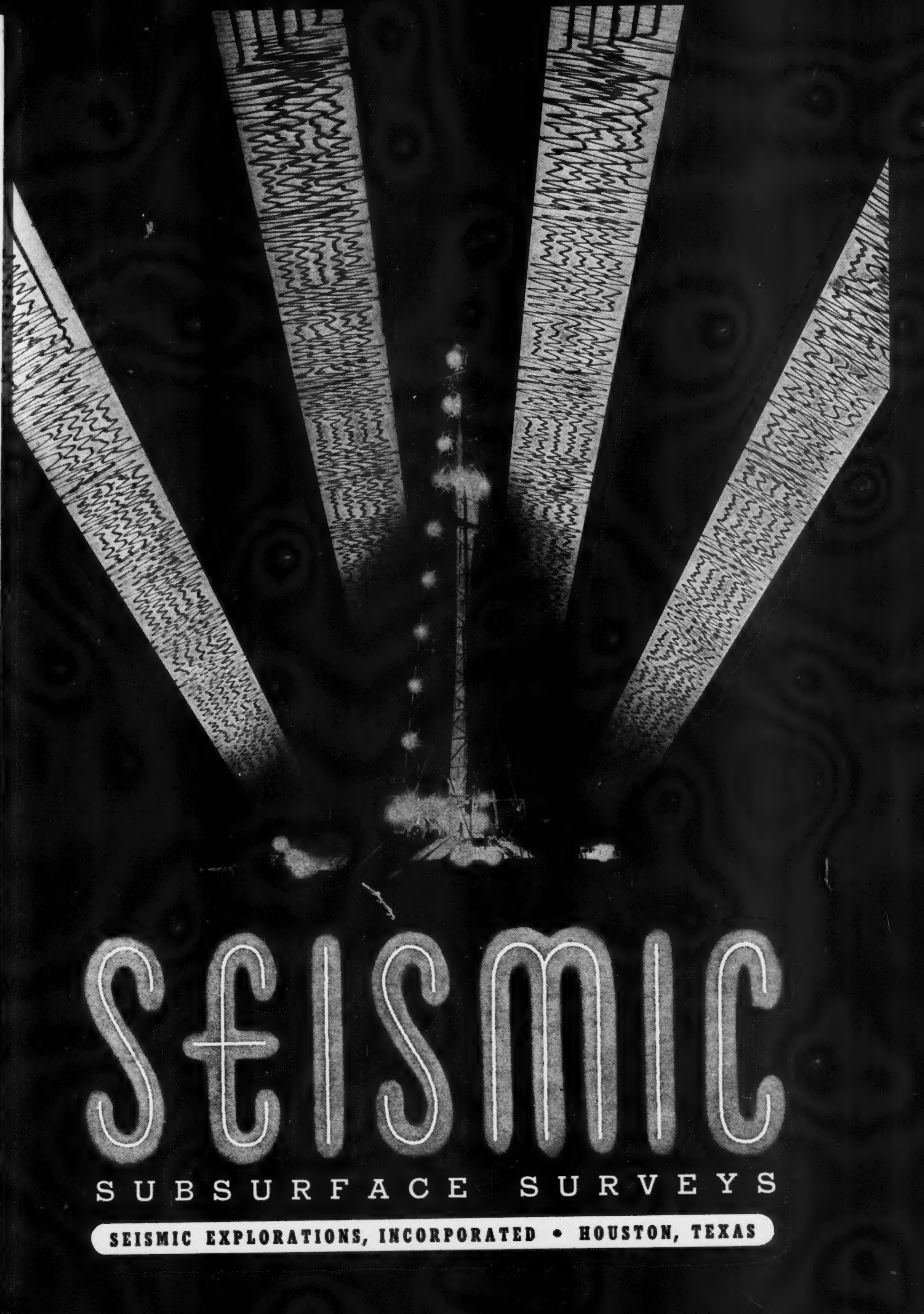
P.O. Box 1925, Washington, D.C.


...reconnaissance

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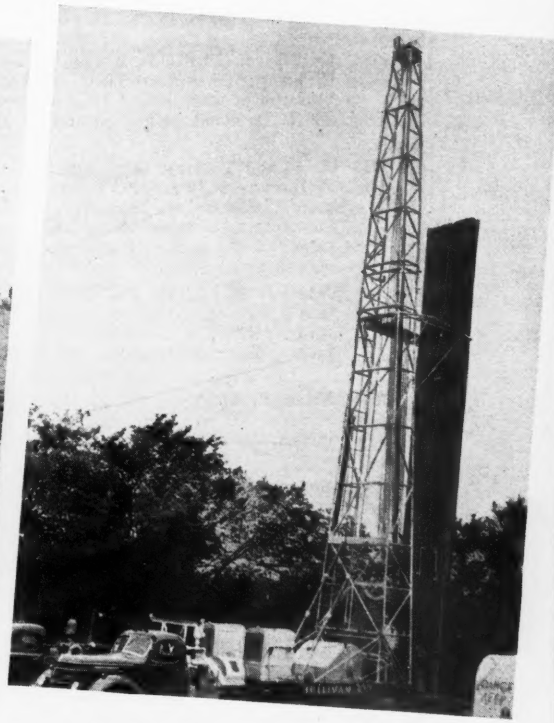

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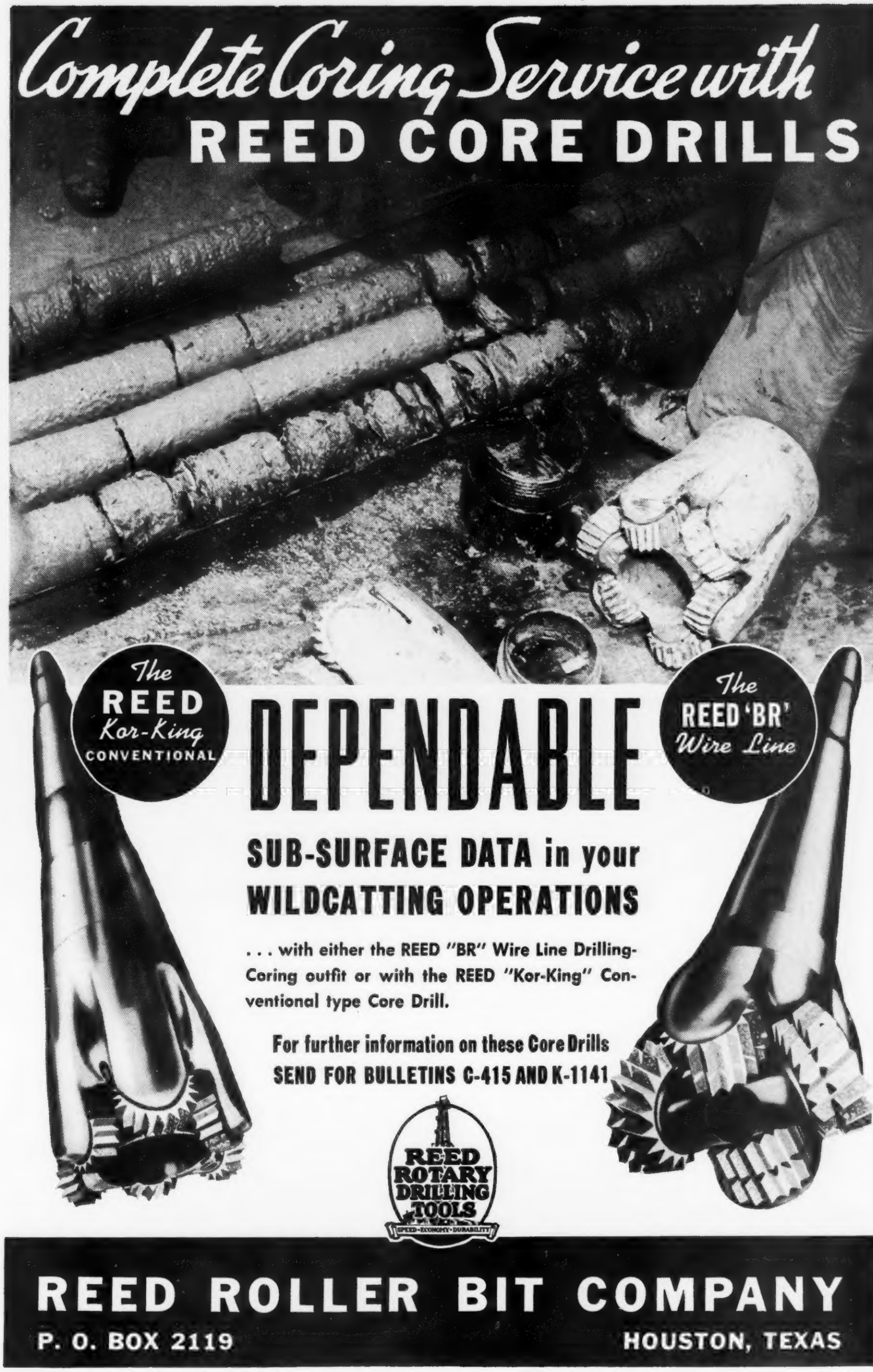
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